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GEOLOGY OF LUCAS COUNTY [Iowa]

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BY

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GEOLOGY OF LUCAS COUNTY

Introduction

Location and Area.—Lucas county is in the south-central part of Iowa just east of a north and south line through the central part of the state and in the second tier of counties from the Iowa-Missouri line. Its position in this tier of counties is sixth east of Missouri river and also sixth west of Mississippi river. Warren and Marion counties are on the north, Monroe county is on the east, Wayne county on the south and Clarke county on the west. It corners with Appanoose county on the southeast and with Decatur county on the southwest.

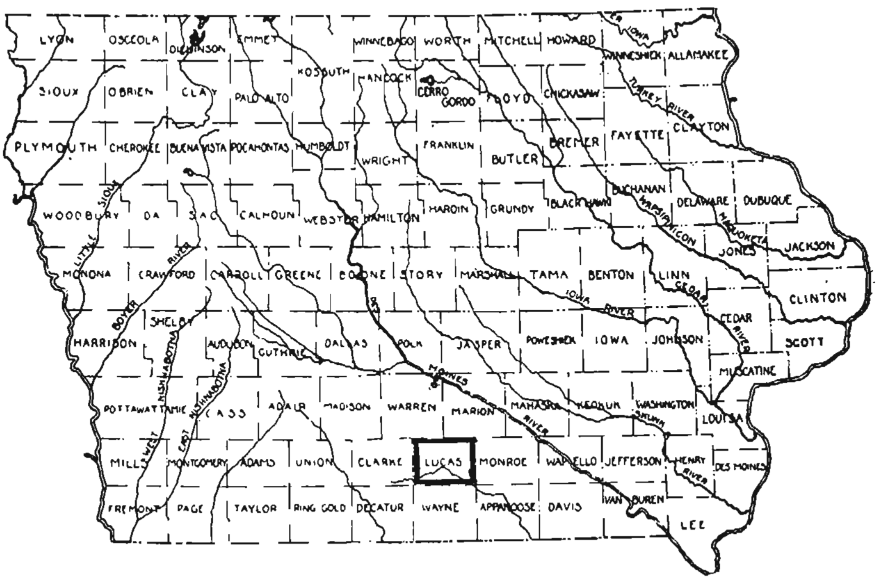

FIG. 1.—Location of Lucas county in Iowa.

This is one of the smaller counties of the state and is rectangular in shape. It contains twelve congressional townships, with approximately 432 square miles or 276,480 acres.[1] The twelve congressional townships are everywhere conterminous with the civil townships, each containing thirty-six sections, and comprise

[1] Area as given by the Fourteenth Census (1920) in Bulletin of Agriculture: Iowa.

townships 71, 72 and 73 north and ranges 20, 21, 22 and 23 west of the Fifth Principal Meridian. The latitude and longitude of the Court House in Chariton, the county seat, are 41° 00′ 55″ N. and 93° 18′ 22″ W.

This county is underlain by formations of the Des Moines series of the Pennsylvanian system and has become an important coal producing county in the last few years. It is served by main lines of the Chicago, Rock Island and Pacific and the Chicago, Burlington and Quincy railroads.

Previous Geological Work.—Very little detailed geological work has been done in Lucas county up to the present time. Most of the early surveys followed the main water courses of the state and did not pass through this county. Geological work on the coal formations has been done in all of the surrounding counties. In the Geological Report of 1870, Orestes H. St. John, under the direction of Dr. C. A. White, then State Geologist, discussed at some length some of the best surface exposures. This county has received some attention also in numerous miscellaneous papers on the general Coal Measures area of south-central Iowa. The reports of the State Mine Inspectors and the Annual Reports of Mineral Production for the state in the volumes of the Iowa Geological Survey also include Lucas county. The work of Dr. George F. Kay, State Geologist, on the Pleistocene of Iowa in its many phases both in and around this county is of the greatest value in interpreting the Pleistocene materials.[2]

Physiography

TOPOGRAPHY AND TOPOGRAPHIC DEVELOPMENT

The topography of Lucas county is of the dissected plain type. The upland areas present an aspect of planeness, though somewhat narrow valleys have been carved into this once extensive plain. This plain was developed during the Pleistocene or Glacial period. The Kansan glacier was the last ice sheet which

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2 The list below includes the important references on Lucas county.
The Geology of Iowa (1870), Vol. II, pp. 77-95.
Iowa Geol. Survey, Vol. II, Coal Deposits (now superseded by Iowa Geol. Survey, Vol. XIX). Vol. XIV, Geology of Clay; Lucas county, p. 447. Vol. XVII, Geology of Quarry Products; Lucas county, pp. 475-476. Vol. XIX, Coal Deposits of South-Central Iowa; Lucas county, pp. 218-227. History of Coal Mining in Iowa; Lucas county, pp. 550-554. Fuel Values of Iowa Coals; Lucas county, pp. 409, 416, 453, 472, 475. Bibliography of Iowa Coals; Lucas county, p. 678. Analyses of Iowa Coals, Lucas county, pp. 504-505. Vol. XXI, Underground Water Resources of Iowa; Lucas county, pp. 949-955. (Same as U. S. Geol. Survey Water Supply Paper 293, pp. 783-788.) Vol. XXII, Annotated Bibliography of Iowa Geology. Vol. XXIV, Road and Concrete Materials of Iowa; Lucas county, pp. 416-417. Bulletin 2, Report on Tests of Iowa Coals.

covered this area and it mantled the pre-Kansan topography with thick drift. Hence, it is impossible to determine in detail the nature of the topography of either the pre-Pleistocene (Pliocene) or pre-Kansan (Aftonian) surfaces although it is known that the Coal Measures (sub-drift) surface, where it is still buried under glacial deposits, has a relief of at least 265 feet within restricted areas.

It is impossible to state with certainty whether the preglacial (Pliocene) surface was level or had considerable relief; whatever it was this surface was covered with a mantle of glacial drift by the Nebraskan ice and on the retreat of this first ice sheet a ground moraine plain with little relief and poor drainage remained. On this plain a considerable thickness of Nebraskan gumbotil developed in Aftonian time. It is uncertain to what extent this Nebraskan gumbotil plain was dissected before the advent of the Kansan ice but the preponderance of evidence is that it was well drained and had essentially mature topography. The streams in some places cut through the drift into the Coal Measures and only patches of the Nebraskan gumbotil plain remained.

Another outstanding fact is that, as mentioned previously, the Coal Measures were extensively eroded in some parts of the county in pre-Nebraskan (Pliocene) or pre-Kansan (Aftonian) time or in both cycles. In Otter Creek township, where the drift is at least 100 feet thick, the present streams have just reached the Coal Measures in a few places. In Jackson township the drift is still thicker, being nearly 200 feet thick. In Union township no Coal Measures are exposed and at Humeston, in the northwest corner of Wayne county, a drilling has shown a thickness of 406 feet of glacial drift.[3] The upland surface slopes from 1104 feet to 1040 feet above sea level between Humeston and Otter Creek township. Drift covered indurated rocks rise much higher both to the east and to the west of the above mentioned localities than do the rocks found at these places and so give evidence that a pre-Kansan valley or valleys extended along the west side of Lucas county.

The same kind of evidence shows that the present Chariton river is flowing over a pre-Kansan valley. Similar evidence

[3] Wayne county report, Iowa Geol. Survey, vol. XX, p. 224.

shows the Coal Measures to have been eroded deeply in parts of Liberty township and in the southeast corner of Pleasant township and also under much of Cedar township.

With the coming of the Kansan ice the Aftonian topography was greatly altered; the valleys were filled and the divides eroded. On the disappearance of the Kansan ice the surface must have been much as it was following the retreat of the Nebraskan ice. There was a level plain with poor drainage and on this plain thick Kansan gumbotil was formed in Yarmouth time. This seems to imply the passage of a very long time before efficient drainage was developed. Lucas county has not been invaded by an ice sheet since Kansan time and it is on this Kansan gumbotil plain that the present drainage has developed. In some places the courses of the present streams, such as Chariton river, were predetermined by slight initial slopes which the streams working headward into the county found advantageous. There are also many small valleys that are strictly post-Kansan in age.

Topographic development progressed to such an extent that the region became essentially mature, though probably with not quite as great relief as it now has, for during Peorian time nearly the entire surface was mantled by loess which in places is fifteen feet thick. Probably some loess was deposited during all of the time from Kansan to Peorian but the Peorian was the time of greatest loess accumulation. Since Peorian time the established streams have continued to deepen and widen their valleys and in general to further reduce the region.

The north and northeastern parts of the county are more maturely dissected than is the southwestern part, hence the maximum relief is in the northeastern part of the county and the most extensive areas of undissected upland are in the western part. One notable topographic feature is the upland divide which extends in an east-west direction across the county south of the middle. The Mormon Trace road follows this divide.

The accordant remnants of the Kansan plain show that if the plain were reconstructed it would slope gently to the northeast. The highest elevations in the county are those of the upland areas at or near Derby in Union township, which are about 1100 feet above sea level. Toward the middle of the county the uplands are at an elevation of about 1040 feet above sea level and in Pleasant township the upland flats are 1000 to 1020 feet above sea level. In Otter Creek township the Norwood upland is 1040 feet above sea level and in Washington township the upland remnants are 1020 to 1030 feet above sea level.

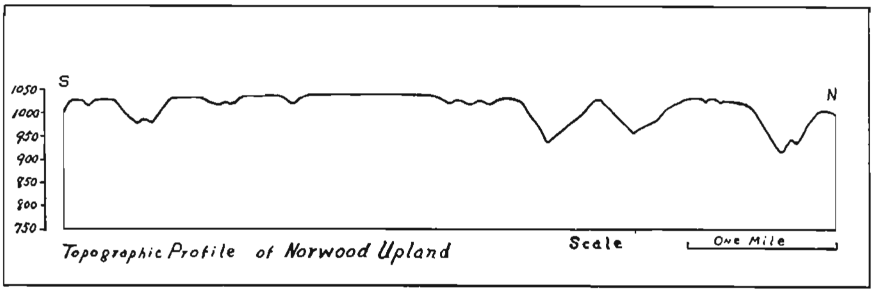


FIG. 2.—Topographic Profile of Norwood Upland.

Figure 2 is a profile from south to north through the upland area nearly one-half mile east of Norwood in Otter Creek township. The south end of the profile is about one-quarter mile north of Harmony school and the north end is at the north county line. Figure 3 is a topographic map of the Norwood remnant upland area, which is typical of all such areas in the county. The figure also illustrates how the streams are working headward and rapidly dissecting these last remnants of upland. Such upland areas are everywhere mantled by loess, which is underlain by the thick Kansan gumbotil. Other similar flat upland areas of peculiarly noticeable extent are: Williamson upland in English township, Belinda upland in Pleasant township, Chariton upland in the center of the county, Derby upland in Union township, and the Russell upland in the corners of Lincoln, Cedar, Benton and Washington townships.

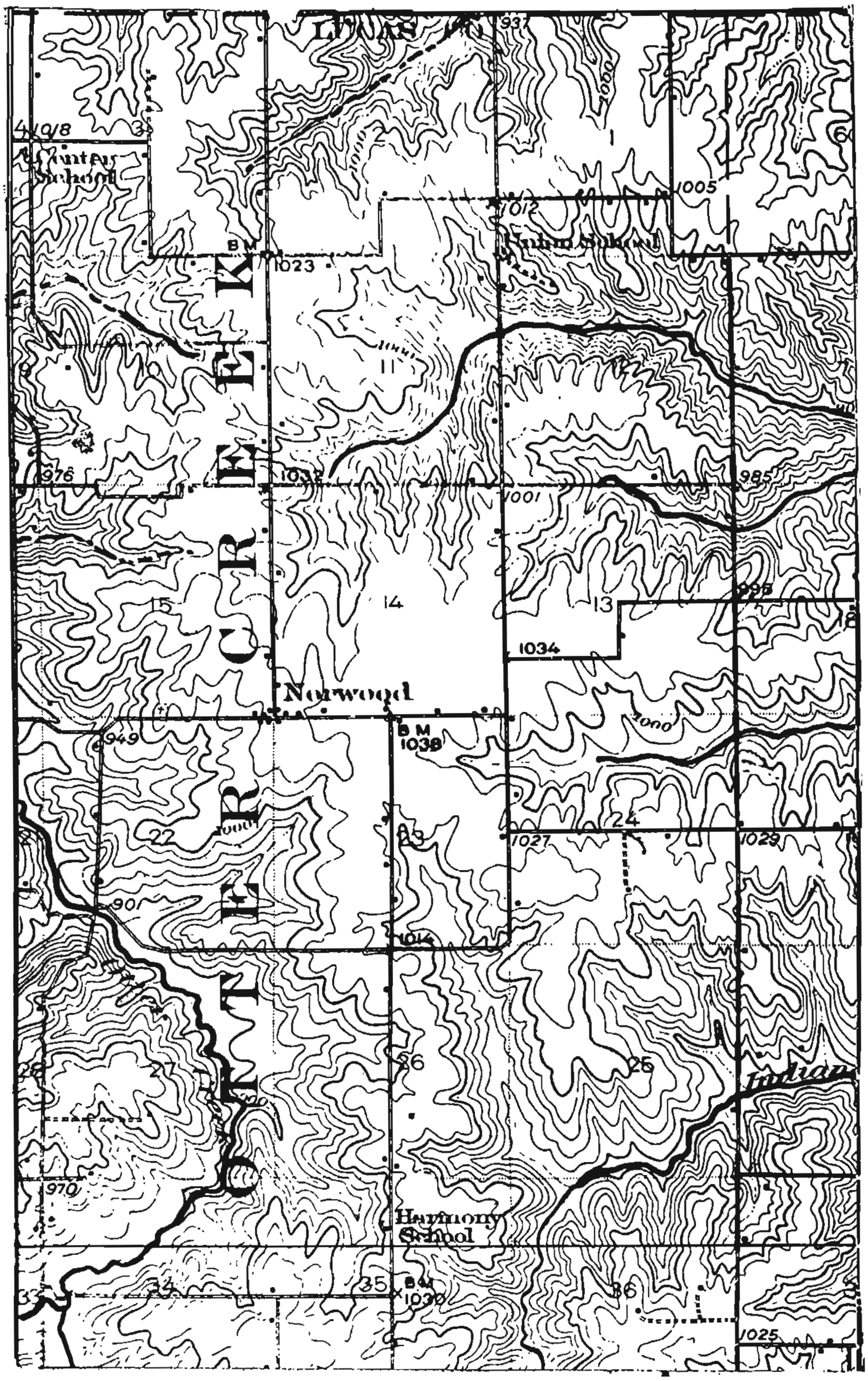


FIG. 3.—The Norwood upland.

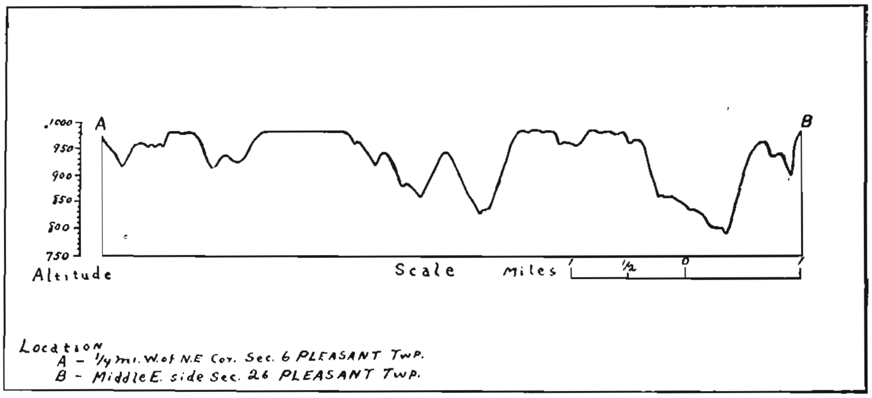


FIG. 4.—Profile across Pleasant township.

Figure 4 is a profile cross section illustrating the topography developed in Pleasant township. The section extends from (A), middle of the north side of the northeast quarter of section 6 to (B) middle of the east side of section 26.

The accompanying table gives a quantitative analysis of the topography by townships in terms of square miles and per cent. The maximum relief in each township is tabulated also.

Topographic Analysis

Township	Upland		Slope		Bottom Flat		Maximum Relief
	Sq. Mi.	Per Cent	Sq. Mi.	Per Cent	Sq. Mi.	Per Cent	
Pleasant	6	16½	28	77½	2	5½	220 ft. N. Fork, North Cedar 200 ft. N. Cedar
English	8½	23½	27	75	½	1½	180 ft. Little White Breast 140 ft. English
Liberty	5½	15½	28	78	2½	7	180 ft. White Breast
Otter Creek	10	27½	24	66½	2	5½	90—100 ft. Otter Creek
Jackson	7	19½	26	72	3	8½	200 ft. White Breast
White Breast	8	22	25½	71	2½	7	180 ft. White Breast
Lincoln	9½	26½	25	69½	1½	4	100 ft. Chariton R. 140 ft. Little White Breast
Cedar	10½	29	25	69½	½	1½	180 ft. N. Cedar 140 ft. Whites Cr.
Washington	11	30½	21	58½	4	11	100—150 ft. Chariton R.
Benton	10	27½	21	58½	5	14	100 ft. Chariton R.
Warren	12	33	20	55½	4	11	90 ft. Chariton R.
Union	16	44	19	53	1	3	90 ft. Chariton R.
County (entire)	114	26+	289½	67+	28½	6+	Highest Pt. 1100 ft. A.T. Lowest Pt. 750 ft. A.T.

Very accurate topographic maps of the Chariton and the Melcher quadrangles cover about half of the county. The townships so mapped are Pleasant, English, Liberty, part of Otter Creek, part of Jackson and nearly all of White Breast, Lincoln and Cedar. In the accompanying table of altitudes, no figures are given for the area covered by topographic maps, with the exception of the railroad stations, and only such altitudes are given as might be useful and as are at points easily located.

Table of Altitudes

	FEET ABOVE SEA LEVEL
Otter Creek township	
SW. corner sec. 16	1040
Bridge middle N. side NE. ¼ sec. 17	920
SW. corner sec. 9	1020
Jackson township	
Lucas, C., B. & Q. RR, station	885.69
Road corner, middle west side of NW. ¼ sec. 34	975
Cleveland, C., B. & Q. RR station	899
Union township	
Derby, Fair ground gate	1100
Derby, C., B. & Q. RR station	1093
Bridge, middle NE. ¼ sec. 13	1010
Warren township	
NW. corner sec. 21	1030
East middle sec. 13	1055
Chariton river, middle SW. ¼ sec. 2	970
Benton township	
East middle sec. 18	1075
Wolf creek brige, NW. corner sec. 22	930
Middle north side sec. 10	1030
Chariton river bridge, SE. corner sec. 24	915
Liberty township	
Oakley, C., B. & Q. RR station	995
White Breast township	
Indianola Junction, C., B. & Q. RR station	1040
Troy, C., B. & Q. RR station	881
White Breast, C., B. & Q. RR station	1042
English township	
Williamson, C., R. I. & P. RR station	1022
Lincoln township	
Chariton, C., R. I. & P. RR station	1014
Chariton, C., B. & Q. RR station	1041
Washington township	
Russell, C., B. & Q. RR station	1035
Middle west side of sec. 15	1010
Chariton river, NE. ¼ sec. 35	850-875
North middle sec. 11	1030

DRAINAGE AND DRAINAGE HISTORY

The drainage of Lucas county is divided into two parts. The south one-third of the county drains into the Chariton river system and the northern two-thirds drains into the Des Moines river system. The Chariton-Des Moines divide crosses the county from west to east.

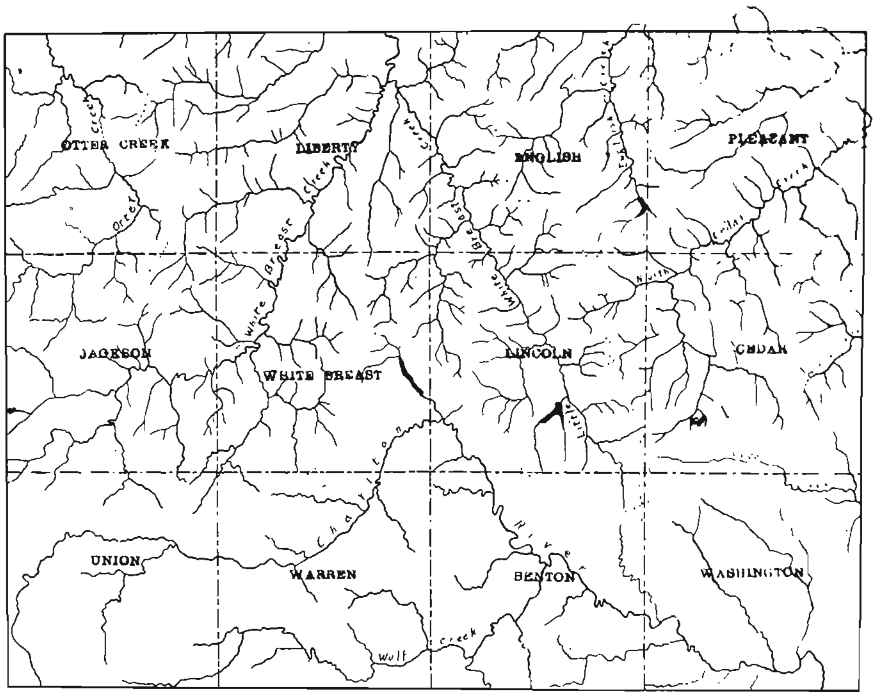


FIG. 5.—Drainage map of Lucas county.

Chariton river with its minor tributaries, including Wolf creek, drains the southern tier of four townships almost in their entirety and also parts of White Breast and Lincoln townships. It empties into Missouri river in Chariton county, Missouri, which is located in the north-central part of that state. The total area included in its drainage basin within Lucas county is approximately 138 square miles, or nearly 32 per cent of the total area of the county. The river has a widely differing gradient in this county; from the north side of section 17, Union township, to the middle of the northeast quarter of section 13, Union township, a distance of 5.3 miles, it has a gradient of approximately one foot per mile; from the latter point to the north part of the southwest quarter of section 30, Lincoln township, a distance of ten miles, the gradient is about nine feet per mile; for the next 22.5 miles of its course to its exit from the county its gradient is about 4.3 feet per mile. The average gradient for the thirty-seven miles of its length in this county is about 4.5 feet per mile. The elevation above sea level of the river at its point of exit from

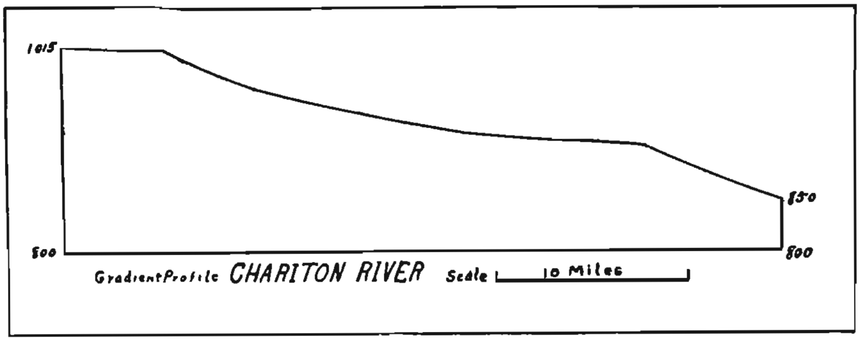


FIG. 6.—Gradient profile Chariton river.

the county is about 860 feet. Figure 6 illustrates the gradient profile of Chariton river. The valley is not deep, 90 to 100 feet below the upland areas, but it has many of the characteristics of maturity. Its walls are gently sloping, the north side having generally a more gentle slope than the south side, and it has a well developed flood plain along most of its course. Figure 7 shows a profile cross section of the valley diagonally across section 30 of Lincoln township and brings out very plainly the more gently sloping north valley wall and the level flood plain.

Coal Measures strata are exposed in the bed of Chariton river only in a few places in Benton and Washington townships. Otherwise, the valley is cut entirely in glacial drift, although it is known that on either side of the valley Coal Measures strata lie under the drift of the uplands at elevations higher than the bed of the river. It is quite obvious, therefore, that Chariton river has developed its present valley on or in a sub-drift valley of at least pre-Kansan age. Well records in section 30 of Lincoln township show the bottom of this ancestral valley to be about fifty feet below the present Chariton channel. The present stream appears to be at grade. Its present course was determined largely by initial slopes on the Kansan gumbotil plain, as

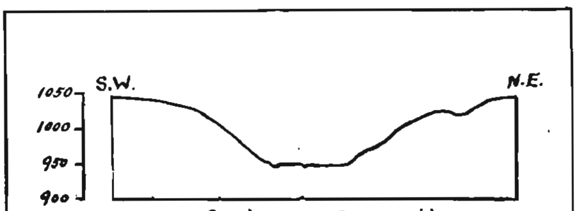


FIG. 7.—Profile of Chariton river valley.

previously explained. The ancestral Chariton river may or may not have flowed in the same direction as the present stream.

The north two-thirds of the county drains into Des Moines river through numerous tributaries and tributary systems. The main divisions of the Des Moines drainage are: Otter creek, White Breast and Little White Breast creeks, English, or Wild Cat creek, North Cedar creek and tributaries. The drainage map (Figure 5) outlines the above drainage basins.

Otter creek flows into South river in Warren county, within whose limits also South river joins the Des Moines. Otter creek drains an area of about thirty-four square miles in Lucas county, or nearly 7.9 per cent of the county, and it has a gradient of three to five feet per mile.

The White Breast-Little White Breast system including Stony creek drains a total of 154 square miles, or a little more than 35½ per cent of the county. White Breast creek proper drains 98 square miles, or nearly 23 per cent of the county, and Little White Breast drains 56 square miles, or approximately 13 per cent of the county. Little White Breast creek joins White Breast creek in Liberty township of this county and White Breast creek flows into Des Moines river in Marion county. The gradient and profile changes in White Breast creek are shown by the map of the Chariton quadrangle. In a distance of 4.8 miles between the 880 and 860 foot contour lines the fall is approximately five feet per mile. Between the 860 and 840 foot contour lines, a distance of 10.2 miles, the fall is two feet per mile and for the next five miles to the 820 foot contour line it is four feet per mile. Between the 820 foot contour line and the 800 foot contour line (outside the county), a distance of seventeen miles, the gradient is 1.2 feet per mile. This profile is shown in Figure 8.

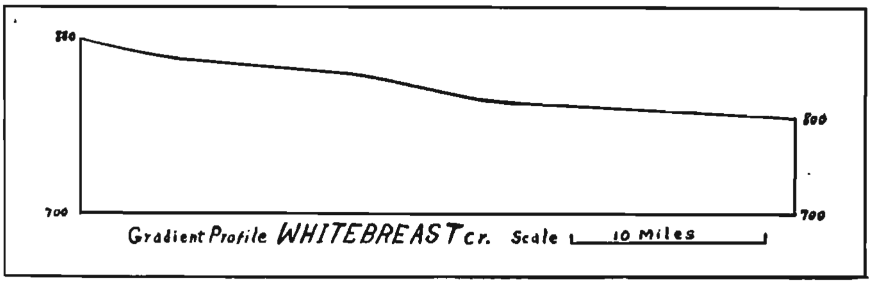


FIG. 8.—Gradient profile White Breast creek.

Figure 9 illustrates the profile of Barker creek, a tributary of White Breast creek, and figure 10 shows a cross section profile of White Breast creek diagonally from northwest to southeast, west of the town of Lucas, from the north middle of section 15 to about

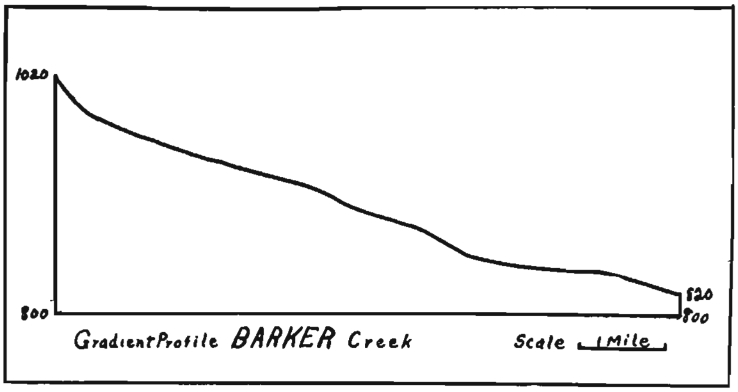


FIG. 9.—Gradient profile Barker creek.

the middle of the southwest quarter of section 23, Jackson township. It illustrates the gently sloping north valley wall and the well developed flood plain; also a tributary valley.

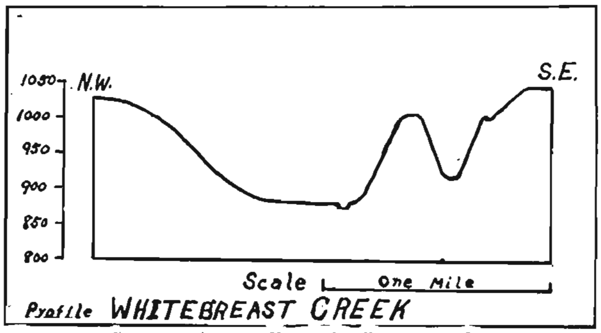


FIG. 10.—Cross section profile White Breast creek.

White Breast valley is the only stream valley in Lucas county that has any terrace development and this is very insignificant. Some suggestion of terraces exists along the south valley wall south and east of Old Cleveland; these are "rock benches" of more resistant Coal Measures materials. Another similar bench of greater extent is in sections 28 and 33, Liberty township, where there is a bench area nearly one-half square mile in extent. The creek formerly flowed west of this bench against the northwest valley wall. The bench is about thirty feet above the present stream and is now somewhat dissected by gullies. These terraces have been developed in the normal course of the stream's history and imply no diastrophic changes. St. John made note of this feature when he visited the county in 1867.

White Breast creek valley is cut in part into glacial till, in part into Coal Measures, and in part into fluvio-glacial material that underlies the till. This material was deposited in one or more preglacial valleys in front of the advancing ice, and has been exposed in the present erosion cycle. It is well exposed along the county line in the east valley wall and at other points along White Breast creek. The upper half of figure 11 shows

FIG. 11.—Coal Measures and fluvio-glacial deposits exposed on White Breast creek.

this material in section. White Breast creek is then in part following pre-Kansan drainage, as is Chariton river. The creek has a fairly well developed flood plain of rich alluvial soil that rests for the most part on Coal Measures strata. It is subject to flood in times of high water. It appears to be at grade below Lucas.

Little White Breast creek has a fall of about 5¼ feet per mile and its valley is narrow, V-shaped and young. In age it is post-Kansan. Figure 12 shows a cross section profile along the highway in sections 32, 5, and 33, Lincoln township.

Stony, Barker and Indian creeks, tributaries to White Breast creek, drain an area mostly in Liberty township where the thickness of the drift seems to be at least equal to the land relief, that is 100 to 140 feet. There seem to be no Coal Measures outcrops along Stony creek as far east as the east part of section 4, Liberty township. No Coal Measures outcrop along Barker creek west of the south side of section 9, Liberty township, with one exception noted below, and perhaps no Coal Measures occur in the valley walls for some distance north and east of this. Coal Measures do not outcrop along Indian creek west of the road in section 30, Liberty township. This seems to point to the conclusion that pre-Kansan erosion had developed a wide valley extending in a northeast and southwest direction across Liberty township. It may have connected with the main valley previously mentioned as extending along the west side of the county and may have included one or several streams. Part of the present White Breast valley also may occupy parts of this subdrift valley. The evidence warrants the conclusion that the area was reduced to a wide level flood plain, at or below the present stream grade, with a Coal Measures divide on the east rising to elevations of 940 to 950 feet above sea level and occupying the northeast part of Liberty and adjacent parts of English townships and swinging around toward the town of Lucas across the south part of Liberty and the north part of White Breast townships. The south point of another such Coal Measures divide reaches from the north into the county in sections 1 and 2 of Otter Creek township. A second explanation is possible: there may still be Coal Measures hills completely covered under the upland divide areas and the three streams, Stony, Barker and Indian creeks, may be occupying separate pre-Kansan valleys. This seems quite unlikely for it would mean a more irregular pre-Kansan surface. It is supported, however, by the presence of Coal Measures about 920 feet above sea level along Barker creek between sections 18 and 19, Liberty township. This is not a surface exposure but was reached in digging a well and is the only known point of the kind. The evidence seems to be preponderantly in favor of the first explanation.

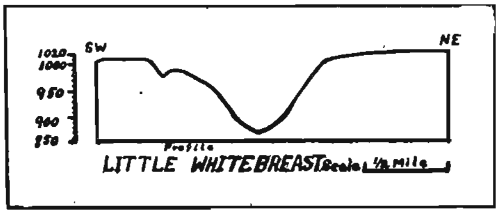


FIG. 12.—Profile of Little White Breast creek.

English or Wild Cat creek flows into Des Moines river in Marion county. It drains about twenty-five square miles, or nearly 6 per cent, of the county and has a gradient of about fourteen feet per mile. It is largely post-Kansan in age; at least most of its course in Lucas county is post-Kansan. Its valley is narrow, V-shaped and young.

The Cedar creek drainage includes a number of streams that do not unite within the bounds of the county but that farther down join Cedar creek, which enters Des Moines river in Mahaska county. The main divisions of the Cedar drainage are: North Cedar creek, Columbia creek, Flint creek, Carruthers creek, Whites creek and South or Little Cedar creek. The total area drained by these creeks is eighty-one square miles, or about 19 per cent of the county. The gradients of all are comparatively high, that of North Cedar creek being about ten feet per mile. Figure 4 illustrates the cross section profiles of some of the creek valleys of Pleasant township.

The northern part of this Cedar drainage is made up of Columbia creek, Flint creek or North Fork and Carruthers creek, which unite into Little North Cedar creek, which in turn empties into North Cedar creek in Marion county. The Little North Cedar drainage comprises about 3½ per cent of the county, or sixteen square miles, in the northeastern part of Pleasant township. All parts of the above creeks, in-so-far as their courses are in Lucas county, are occupying young V-shaped post-Kansan valleys and have exposures of Coal Measures strata at various points in their valley walls. There is evidence that the Coal Measures strata were quite deeply cut out in parts of sections 9, 10, 15, 16, 21 and 22 of Pleasant township during some previous erosion cycle.

North Cedar creek drains about forty-five square miles, or nearly 10½ per cent, of the county and flows into Cedar creek, which joins Des Moines river in Mahaska county. Its narrow valley is deeply incised into the glacial filling of the pre-Kansan valley which it follows and at a few places into the Coal Measures strata. Its very narrow rich alluvial flood plain is subject to overflow in time of high water. North Cedar creek is, like Chariton river and White Breast creek, at grade and probably has not cut quite as deeply as its ancestral pre-Kansan stream.

It does not seem to carry as much water as formerly and is building up its flood plain.

Whites creek drains about eight square miles in the east part of Cedar township and has cut deeply into the glacial drift. It joins Coal creek in Monroe county and Coal creek empties into South Cedar, which flows into Cedar creek in Marion county. Whites creek probably is post-Kansan in age though it drains part of a deeply drift covered area from which the Coal Measures strata were extensively eroded in pre-Kansan time.

South Cedar creek drains about twelve square miles in Cedar and Washington townships and like Whites creek flows into Coal creek in Monroe county. It, like Whites creek, probably is post-Kansan in age and has not exposed Coal Measures.

It has been shown that the deposition of Kansan drift filled all pre-Kansan valleys except in-so-far as such old valleys were reflected on the new Kansan surface as initial slopes, which were controlling factors in locating the present drainage lines. Active drainage and erosion did not come into existence until the Kansan gumbotil was developed and so the present drainage systems and the present topography have been developed not only since Kansan glacial time but since late Yarmouth time. The present drainage lines were established before the maximum loess deposition, that is in early or pre-Peorian time. The development of the present valleys has revealed some of the principal pre-Kansan valleys and clearly some of the present streams are flowing in valleys that coincide essentially with their ancestral valleys.

The streams seem to carry less water on the average the year around than formerly. This seems to be due not to any decrease in rainfall but rather to a quicker run-off, which is the result of deforestation of the valley slopes. This forest cover formerly retained large amounts of the rain water, which gradually was fed to the streams as ground water between rains. But when the hillsides are unprotected by the forest covering they are deeply eroded by the more rapid run-off and the material supplied by this gully-washing is carried into the main streams by the scores of small tributaries. The main streams are overloaded and, if the precipitation is heavy, the sediment is deposited on the flood plains in time of high water. The water quickly drains off and the channels are soon dry until the next heavy rain. The main streams are so overloaded throughout the period of rapid run-off that their effectiveness in deepening their channels is negligible. St. John reported a detailed section of Coal Measures strata exposed at Wheeler's bridge in Liberty township which he visited in 1867; in 1924 the same stratum is still exposed in the bed of White Breast creek and to no greater depth. White Breast creek at this point at least has not deepened its channel a measurable amount in more than half a century. If these streams were not already at grade they have been hastened to that condition through the settlement of the county by man and through his subsequent activity.

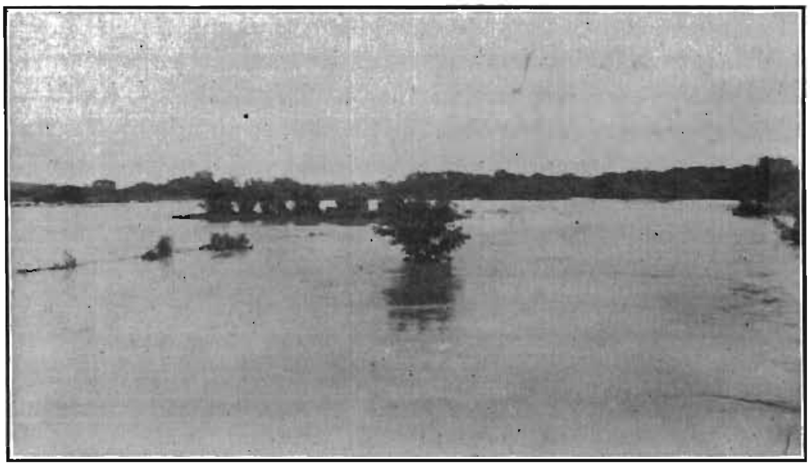


FIG. 13.—White Breast creek in flood about July 23, 1924.

Attention has been called to the more gently sloping north valley walls in connection with the cross section profiles of Chariton river valley and White Breast creek valley. In general it is true that streams whose course is east or west, or those that have much of an easterly or westerly component, have very gently sloping north valley walls while the south valley sides are steeper. This fact has been noted quite generally in southern Iowa and at least two explanations have been suggested. G. K. Gilbert[4] attributed such phenomena to deflection of the streams due to the rotation of the earth. Gilbert's theory is considered inadequate and is not further considered. The most plausible explanation

[4] Gilbert, G. K., Memoirs of the Nat. Acad. Sciences, vol. III, First Memoir, Washington, 1884.

and the one adopted here was suggested by Calvin.[5] He attributed the phenomena to a more rapid weathering and erosion on the south-facing slopes. Calvin states "As soon as these streams cut channels of any considerable depth, the two sides of each channel were differently affected by the agents of erosion. The northward facing surfaces suffered less than the opposite side of the

FIG. 14.—White Breast creek in time of comparatively low water.

channel from the alternations of freezing and thawing and consequent effects of erosion, in early winter and spring. They were less affected by the droughts of summer, which tended to check the growth of vegetation and render the surface more pulverulent and more easily attacked by dashing rain storms. The result was that as the channel was deepened the north side of the valley receded more rapidly than the south, the slopes soon became gradual."

Stratigraphy

GENERAL RELATIONS OF STRATA

The only indurated rock exposed in Lucas county belongs to the Des Moines series of the Pennsylvanian system and over much of the county this is deeply covered by glacial drift. Good exposures are limited mostly to the northeast six townships, although a very few good but small exposures are known in the south and west tiers of townships. Approximately the upper half of the Des Moines is known from surface exposures and the

5 Calvin, S., Geology of Johnson county: Iowa Geol. Survey, vol. VII, p. 51; 1896.

unexposed 50 to 250 feet of the series is known from drill records made in prospecting for coal. It is doubtful, also, if the upper division of the Des Moines series, the Pleasanton, outcrops at more than one or two places, owing to the extensive pre-Kansan erosion along the west side of the county.

The relations of the several series and stages are shown in the accompanying table. A discussion of these formations will be given in the pages that follow.

Synoptical Table

Group	System	Series	Stage	Character of Rocks
Cenozoic	Quaternary	Recent		Alluvium and other surface soil
		Pleistocene	Peorian	Greatest loess deposition
				Probable loess deposition
			Yarmouth	Gumbotil (Kansan)
			Kansan	Glacial drift
			Aftonian	Gumbotil (Nebraskan)
			Nebraskan	Glacial drift
Paleozoic	Pennsylvanian	Des Moines	Pleasanton[6]	Thick shales, thin coal seams, some fairly persistent limestones, sandstone locally. Chariton conglomerate
			Henrietta	Persistent beds of shale and limestone and lenses of sandstone and thin coal
			Cherokee	*Upper*. Mostly thick shales with thin limestones and sandstone. Coal. *Lower*. Shale and sandstone, some coal
	Mississippian	Iowa	Ste. Genevieve	Limestone and shales (not exposed)
			St. Louis	Limestone (not exposed)
			Undifferentiated	(not exposed)

[6] The Pleasanton, with the exception of the Chariton conglomerate, is known from only one or two exposures.

NOMENCLATURE AND DEFINITIONS

The group and system names given in the above table are accepted generally. The Iowa Geological Survey has designated the Pennsylvanian as a system, making the Missouri a series.[7] Hence the Des Moines is a series paralleling the Missouri and its stages or formations are called the Cherokee, Henrietta and Pleasanton, following the nomenclature and definitions of the Missouri Bureau of Geology and Mines.[8] In Iowa the Cherokee includes all strata from the base of the Des Moines to some distance above the Mystic-Lexington coal bed of Bain, placed by him in the Appanoose formation.[9] Bain's Mystic coal bed is then in the upper part of the Cherokee. The lower part of the Cherokee has much more sandstone than the upper more persistent beds. The Henrietta formation includes the remainder of Bain's Appanoose formation. In Missouri it includes the Fort Scott limestone at its base, the Pawnee limestone at the top and the Labette shale in the middle. The Pleasanton includes strata from the top of the Henrietta to the base of the Hertha limestone,[10] the basal member of the Missouri series. In Missouri a well marked unconformity is recognized within the Pleasanton as channel sandstone deposits that have not so far been seen to lie on or cut across upper Pleasanton or higher formations have been noted in many places in that state. These sandstone deposits are considered to be younger than the Henrietta and the lower Pleasanton and to have been made at a time of general emergence and erosion. Hinds and Greene[11] state that, "Bain's Chariton Conglomerate of Appanoose County, Iowa,[12] is evidently the same as that recently found in Schuyler and adjacent counties in Missouri." The Chariton conglomerate is exposed at the surface in Pleasant township, Lucas county; at least there is a channel deposit of sandstone and conglomerate that is here so correlated. In addition several buried sandstone channel deposits seem to belong to the same type, but these are known only from drillings

7 Tilton, J. L., The Missouri Series of the Pennsylvanian System in Southwestern Iowa: Iowa Geol. Survey, vol. XXIX, pp. 223-314.

8 Hinds and Greene, The Stratigraphy of the Pennsylvanian Series in Missouri: Missouri Bureau of Geology and Mines, vol. XIII, Second Series.

9 Bain, H. F., Geology of Appanoose County: Iowa Geol. Survey, vol. V, pp. 374-409.

10 Tilton, J. L., Geology of Clarke County: Iowa Geol. Survey, vol. XXVII, pp. 105-170; also Tilton, J. L., The Missouri Series of the Pennsylvanian System in Southwestern Iowa: Iowa Geol. Survey, vol. XXIX, pp. 223-314.

11 Op. cit., pp. 94 and 95.

12 Bain, H. F., Op. cit., pp. 394-398.

and not enough is known of their extent to enable one to map them. To quote further from the above work of Hinds and Greene: "The Red Rock sandstone of Marion[13] and Jasper[14] counties, Iowa, lies in a channel 2½ to 3 miles wide that has been traced for 27 miles from Eagle Rock northeastward. This sandstone has a maximum thickness of 100 feet and has all the characteristics of the Warrensburg and Moberly sandstones. Iowa investigators have assigned its origin to contemporaneous erosion, but Miller notes its similarity to the Warrensburg, and Williams, from a study of the cross-bedding, considers it to have been made by a current of water flowing in a definite direction. There are other similar channels in Guthrie, Boone and other Iowa counties that may be contemporaneous with those in Missouri."

The Coal Measures strata of Lucas county are correlated with equivalent strata in Missouri. It would be very desirable to be able to subdivide the Pennsylvanian of the Western Interior coal field into units equivalent to the subdivisions of the standard Pennsylvania section, but sufficient data for such a step are not yet in hand.

"It is to be hoped that additional paleontologic evidence may result in the near future in a new subdivision of the Pennsylvanian into groups correlative with those in the Appalachian region. It is fairly certain that the lower part of the Cherokee shale is of Pottsville age and the upper part is of Allegheny age. From incomplete collections already made it is tentatively suggested that Allegheny time ends at the horizon of the unconformity in the upper part of the Pleasanton formation and that Conemaugh time ends well up in the Shawnee formation."[15]

The stage names Aftonian, Kansan, Yarmouth and Peorian are now quite generally accepted and need no particular explanation. In 1909 Shimek[16] proposed the name Nebraskan for the older drift in place of the terms pre-Kansan or sub-Aftonian. Kay in 1916 proposed the term Gumbotil.[17]

The two older glacial drift sheets are represented by till made

13 Miller, B. L., Geology of Marion County: Iowa Geol. Survey, vol. XI, pp. 153-161; 1901.

14 Williams, I. A., Geology of Jasper County: Iowa Geol. Survey, vol. XV, pp. 316-322; 1905.

15 Hinds and Greene, "The Stratigraphy of the Pennsylvanian Series in Missouri," p. 7.

16 Shimek, B., Aftonian Sands and Gravels in Western Iowa: Bul. Geol. Soc. America, vol. 20, p. 408; 1909.

17 Kay, G. F., Gumbotil, a New Term in Pleistocene Geology: Science, N.S., vol. 44, pp. 637-638; 1916.

up of clay, sand, gravel and bowlders in the most heterogeneous relations. On the basis of lithology, color, degree of oxidation or leaching these two tills are indistinguishable one from the other in the exposures seen in Lucas county. They are distinguishable only when they are exposed in a single section and are separated by Nebraskan gumbotil, or when the above three formations are exposed close enough together to establish their stratigraphic relations.

Aftonian time is represented by the Nebraskan gumbotil,[18] which is developed on the lower till. No peat beds occur in the county at this horizon or at any other horizon so far as is now known. The many small lenses of gravel associated with till which are present in this county would, no doubt, at a former time, have been interpreted to be Aftonian[19] but the writer finds no evidence supporting such a view. Gravels are not regarded as being necessarily indicative of interglacial time, either Aftonian or Yarmouth, though such beds may happen to occur at those horizons.

The Kansan till overlies the eroded Aftonian surface, the dissected Nebraskan gumbotil plain, as previously explained. Yarmouth time is represented in part by the Kansan gumbotil.

The Illinoian, Sangamon and Iowan stages are not represented by definite, distinguishable deposits but some of the loess may have been deposited during one or more of these times.

The time of greatest loess deposition was the Peorian, and the loess of south-central Iowa is correlated with the Iowan loess of eastern Iowa. The time since this period of greatest loess deposition is represented by weathering, erosion, the development of soil and the accumulation of alluvial deposits.

PALEOZOIC HISTORY AND STRUCTURE

Records are not available of any drillings that go more than a short distance into the Mississippian rocks. Such records as are at hand show quite clearly the stratigraphic relations of the Pennsylvanian and Quaternary systems and the Pennsylvanian-Mississippian contact. Three diamond drill holes were sunk to depths of over a thousand feet within a small area two or three miles east of the town of Lucas more than a score of years ago.

18 Kay, G. F., and Pearce, J. N., Origin of Gumbotil: Jour. Geol., vol. XXVIII, p. 89; 1920.
19 Calvin, S., Aftonian Gravels: Proc. Davenport Acad. Science, vol. X, pp. 18-31.

The records of these drillings were not filed and preserved for future reference and such records as were kept privately for a long time were completely lost by fire only a few years ago. The only value these costly drillings now have is one of inference only and that of negative results. Evidently these drillings did not penetrate anything of economic value below the Lower coal, and it was already known. They evidently did not penetrate important artesian aquifers, oil bearing horizons or zones of mineralization. The driller, not being a geologist nor informed on the subject of stratigraphy, could not draw any conclusions as to the horizons he had penetrated, so no direct information is in hand as to the elevations or thicknesses of the deeper strata that underlie the county.

Deep drillings have been made at numerous places north, east and south of the county and much can be inferred from these records, as they have been carefully interpreted. Such interpretations and conclusions as are given below for Lucas county are tentative and may not prove correct in detail, although they should be at least suggestive.

The deep well records[20] of Des Moines, Pella, Station No. 10 (sec. 8, Bluff Creek township, Monroe county), Oskaloosa, Centerville and Corydon are tabulated in summarized form in the accompanying table. The thicknesses of the systems, series or formations and also the elevations of the tops of the systems and formations are stated. A noticeable but natural feature is the great range in thickness of the various formations. Exact information for Lucas county is in hand on only the Quaternary and Pennsylvanian systems and the upper Mississippian surface. The assumption is that the stratigraphic relations of the deeper strata are essentially as they are in other parts of the state where they are known from drillings or where they outcrop. A complete upper Mississippi valley Paleozoic section from the Pennsylvanian down is quite certainly represented.

The last double column in the accompanying table gives for Lucas county the known and what seem to be the most probable thicknesses for the various strata and also the probable elevations above or below sea level of the systems, series or forma-

20 Well records taken from Underground Water Resources of Iowa, by W. H. Norton and others, Iowa Geol. Survey, vol. XXI.

SYSTEM, SERIES or FORMATION	DES MOINES Ft. Thick	DES MOINES A.T.	PELLA Ft. Thick	PELLA A.T.	No. 10 Monroe Co. Ft. Thick	No. 10 Monroe Co. A.T.	OSKALOOSA Ft. Thick	OSKALOOSA A.T.	CENTERVILLE Ft. Thick	CENTERVILLE A.T.	CORYDON Ft. Thick	CORYDON A.T.	Average Thickness	LUCAS County (Tentative Data) Thickness	LUCAS County (Tentative Data) Elevation
Quaternary	14	+872	135	+868	127	+895	50	+843	90	+1017	731	+1110	?	125	+1040
Des Moines	488	+858	195	+733	None		111	+793	436	+927			310	200 to 400	+940 to +675
St. Louis etc.	200	+374	270	+538	460	+768	449	+682	515	+491	357	+379	375	375	+736 to +537
Kinderhook	160	+174	125	+268	164	+308	110	+238	50	−24	87	+22	116	116	+240 ±
Devonian	80	+14	420	+143	597	+147	356	+123	260	−83	65	−65	480	535	+124 ±
Silurian	507	−66							180	−343					
Maquoketa	33	−573	190	−277			124	−233					120	120	−411 ±
Galena-Platteville	508	−606	350	−467					200	−523			353	353	−531 ±
St. Peter	39	−1114	15	−817					40	−723			31	31	−884 ±
Shakopee	124	−1153	60	−832						−763			125(?)		
New Richmond	94	−1277											100(?)		
Oneota	175	−1371							715				200(?)		
Cambrian-undifferentiated	582	−1546													
Total Depth	3000		1760		1345		1200		2495		1240				

tions. Sea level elevations are abbreviated A. T. (above tide) plus or minus. The evidence on which these judgments are based cannot all be shown in the table, but it is believed that the data presented are the best that are now available. The conclusions, as previously stated, do not represent finality but rather, it is hoped, progress on these problems. It is desirable that additional and fuller data be obtained and preserved for use in the future.

The elevations of the Coal Measures surface can be accounted for on the basis of pre-Kansan and recent erosion for the most part but there is little doubt that this surface is in part structural. In general the strata have a southwesterly monoclinal dip, but this dip is not uniform and is less across Lucas county than it is in counties to the east and northeast or to the west and southwest. All strata seem to dip more steeply west of a line only a short distance east of the Clarke-Lucas county boundary. The structure of the Des Moines series in Lucas county will be dealt with more fully later.

The Mississippian system appears to thicken from Des Moines to the south and southeast and its surface, while very irregular, is lower at Des Moines, Centerville and Corydon than at Pella, No. 10 or in Lucas county. As will be shown later, this Mississippian surface has a relief of more than 200 feet and this fact might account for the above differences, assuming that high points had been struck at Pella, No. 10, Oskaloosa and in Lucas county, and low points at Des Moines, Centerville and Corydon. The top of the Mississippian is known to be at higher elevations near Des Moines than that given in the table. This view would seem more probable were it not for the fact that the top of the Kinderhook beds and the top of the Devonian system show a similar rise in the middle wells and by inference in Lucas county. This fact seems hardly fully explainable on the basis of unconformities and suggests a structural explanation.

The surface of the Mississippian at its lowest recorded elevation in Lucas county (541 feet above sea level) is higher than the top of the same system at Des Moines, Centerville and Corydon. The highest elevation of the Mississippian system recorded in Lucas county is nearly 200 feet higher (736 feet above sea level) and is essentially accordant with the top of the system at No. 10 and at Oskaloosa. This latter accordance may be accounted for in part by assuming the presence of younger Mississippian strata under Lucas county and at No. 10 than at Des Moines and Corydon. The higher elevation at No. 10 and at Oskaloosa is in part explainable on the basis of the southwesterly dip of the formations across this part of Iowa.

The Devonian surface shows a condition paralleling the above even more clearly than do the higher strata. It is low at Des Moines, Centerville and Corydon and higher by more than 100 feet at Pella, Oskaloosa and, by inference, under Lucas county. The combined thickness of the Devonian and Silurian systems is not so noticeably greater to the southward as is the thickness of the Mississippian. The relations of the Maquoketa and Galena-Platteville formations are not so well shown, as these strata have not been reached in all cases, and the St. Peter surface also is quite problematical. However, the St. Peter seems to be lowest at Des Moines and highest at Centerville and at intermediate elevations at Pella and in Lucas county. Its surface is more nearly a plane than are the higher surfaces.

The Geologic Map of Iowa in volume XXI of the Iowa Survey reports shows the St. Peter surface as occurring in Lucas county at depths from 1000 feet to 1250 feet below sea level, from east to west across the county. According to the accompanying table the St. Peter should be reached at depths from 800 feet to 1000 feet below sea level from east to west across the county. At Chariton the St. Peter might be expected at 2050 feet or less below the surface (surface elevation 1040 feet above sea level). There is a sharp change in dip along the west side of the county and this change becomes greater in a southwesterly direction. However, it is not believed to be great enough to carry the St. Peter as low as 1400 feet below sea level at Osceola, Clarke county, as stated by Tilton.[21] It is thought, from evidence known from Lucas county, that the St. Peter should be reached at about 1200 feet below sea level at Osceola.

The base of the Pennsylvanian (Des Moines) has been mapped as occurring a little over 500 feet to less than 400 feet above sea level, from east to west across Lucas county.[22] However, the known base of the Pennsylvanian ranges from less than 537 feet to 736 feet above sea level and rests unconformably on the Mis-

21 Tilton, J. L., Geology of Clarke County: Iowa Geol. Survey, vol. XXVII, pp. 158-162.
22 Iowa Geol. Survey, vol. XXI, p. 1001.

sissippian surface, which has a relief of at least 200 feet. The earlier estimate is in error by fully 200 feet.

Paleozoic deposition in this part of North America took place in a wide shallow geosyncline which varied greatly in depth and at times was entirely drained. The sediments were for the most part fine in texture and probably were derived from rather low lands. If there were high lands to the north and northeast they were quite remote. This geosyncline was, most likely, just a deeper part of the more or less widespread seas that covered the upper Mississippi valley region periodically during the Paleozoic era. As sedimentation went on this great depression deepened or sank as it filled but less rapidly. By the end of the Paleozoic era the lower formations, such as the St. Peter, came to be greatly concave while the overlying ones were less deformed by the settling that accompanied deposition and were more nearly horizontal.

The history of the deeper rocks is not revealed and a detailed interpretation is not attempted.

Towards the close of Pella or Ste. Genevieve time or possibly as late as early Chester time, the geosyncline was elevated and somewhat reversed; the deeper and more central parts were raised more than the shallower lateral parts. This tended to make the lower formations less concave and the younger formations not only less concave but even slightly convex. As the sea withdrew from the upper Mississippi valley the Mississippian rocks were subject to weathering and erosion and the area of Lucas county remained a land area to the close of Mississippian time. There may have been some tilting to the southwest at this time, giving these formations in part their southwesterly dip. This monoclinal structure is not simple but there are minor folds, small anticlines and synclines and possibly domelike warps that are not strictly classifiable as anticlines.

Following the period of uplift and erosion there was further general submergence and a return to geosynclinal conditions at "critical level", the condition favorable for coal formation. The geosyncline was now shallower than it had ever been before and it was occupied by the shallow Pennsylvanian seas and embayments that covered large areas in what is now the upper Mississippi valley. The Coal Measures formations came to overlie unconformably the older formations. The Pennsylvanian submergence involved parts of Iowa, Missouri, Nebraska, Kansas and other areas to the southwest, in general the Western Interior Coal Field.

In Pleasanton time (horizon of unconformity recognized in Missouri) there occurred a period of uplift and erosion with subsequent subsidence and deposition of channel (terrestrial) deposits. The upper part of the Pleasanton formation was deposited under conditions similar to those prevailing prior to the period of uplift and the area was generally submerged. Later, perhaps near or at the end of Pleasanton time, there was differential movement resulting in a further tilting to the southwest; terrestrial conditions prevailed to the northeast and marine conditions to the southwest. Following this the Missouri series was deposited under generally more stable conditions than had prevailed during Des Moines time, but also with many fluctuations. Lucas county at this time may have been either a land area or under the shallow sea or alternating in position. If any Missouri sediments were deposited over Lucas county they were removed prior to glaciation.

At the end of Pennsylvanian time the geosyncline involving south-central Iowa was uplifted and still further reversed, with the result that the lower formations, like the St. Peter, that had been concave came to be nearly plane and the upper formations, such as the Devonian and Mississippian, came to be relatively convex with a few minor warps. One of these minor structures extends into Lucas county from the northeast. The area of south-central Iowa was subject to weathering and erosion from the uplift following Pennsylvanian time to the Pleistocene, when the region was rejuvenated by two glaciations.

The average elevation of the Lower coal in Pleasant township is about 720 feet above sea level and its average elevation in the vicinity of Lucas is about 620 feet above sea level. This shows that the coal dips about six feet per mile in a direction approximately 18 degrees south of west. The White Breast coal horizon has a dip of about five feet per mile in the same direction. If this difference in dip is a real difference and not due to the undulatory nature of the beds the Cherokee shales seem to thicken in a southwesterly direction. West of Lucas the strata have a much steeper dip. The formations have an appreciable dip to the northwest (as much as fifteen to twenty feet per mile in places) from a line drawn from a point about three miles northeast of Lucas to the northeast corner of the county. They have a very slight dip to the south from the same line.

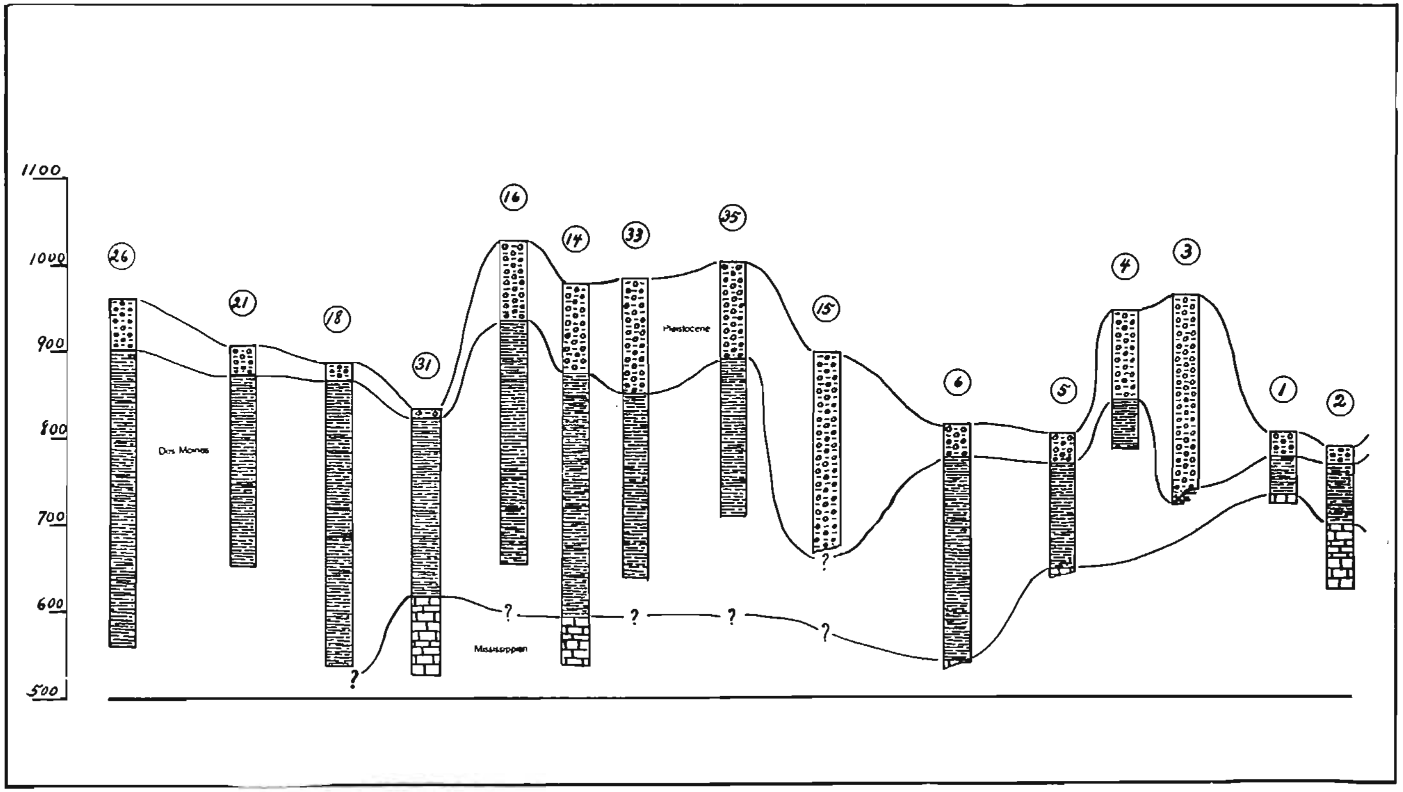
THE MISSISSIPPIAN-PENNSYLVANIAN AND PENNSYLVANIAN-PLEISTOCENE UNCONFORMITIES, AND THE THICKNESSES OF THE PENNSYLVANIAN AND PLEISTOCENE DEPOSITS

The existence of erosional unconformities between the Mississippian and Pennsylvanian and Pennsylvanian and Pleistocene systems is well recognized but quantitative data in geological reports are usually obscured by the mass of other information. In many cases such data are not given at all. The Mississippian surface in Lucas county is known only from drill records made in prospecting for coal, hence it is difficult to correctly estimate the quantitative effect that differential uplift or subsidence has had on the attitude of this surface, but that effect does not seem to have been great.

The accompanying table and Plate I summarize the important data on these unconformities. Plate I gives generalized sections of fifteen coal prospect holes. They are numbered in the circles above and are similarly designated on the general map. The vertical scale at the left refers to elevations in feet above sea level; necessarily it is greatly exaggerated. The horizontal spacing is not proportional to actual distance between holes but is relative when the holes are projected from their normal locations onto a straight line extending from section 25, White Breast township (location of No. 26), to section 13, Pleasant township (location of No. 2). This is not an exact profile section of the surface nor a true structure section of the geology, but it is of value in order to bring together the drill logs that contain the data. The conclusion has been reached, after a careful study of more than forty drill records from the same part of the county, that if enough records were available from holes drilled to great enough depth and in a straight line almost anywhere through the county, they would reveal the same relations in detail that Plate I reveals in general.

Mississippian Surface.—Logs 5 and 6 are approximately one mile apart and the relief on the Mississippian surface between

Drill Section No.	26	21	18	31	16	14	33	35	15	6	5	4	3	1	2
Township-Section	W.B.25	Ln. 7	Ln. 15	Lib. 12	Ln. 2	Cdr. 7	Eng. 35	Eng. 24	Cdr. 3	Pl. 27	Pl. 26	Pl. 22	Pl. 22	Pl. 12	Pl. 13
Elevation of Curb, feet above sea level	960	907	888	832	1030	980	986	1004	900	818	805	948	968	808	791
Thickness of Drift, feet	60	35	23	20	92	104	134	113	225	40	35	104	226	30	21
Elevation of top of Coal Measures, feet above sea level	900	872	865	812	938	876	852	891	Not Reached	778	770	844	742	778	770
Thickness of Coal Measures, feet	340	220	328	198	284	281	214	181	?	237	122	56	?	42	70
Elevation of Lower Coal, feet above sea level	Cut out	653	688	?	710	?	?	718	Cut out	?	761	794	Cut out	750 ?	721
Elevation of top of Mississippian, feet above sea level	Not Reached	Not Reached	Not Reached	614	Not Reached	595	Not Reached	Not Reached	Not Reached	541	648	Not Reached	Not Reached	736	700
Bottom of Hole, feet above sea level	560	652	537	526	654	539	638	710	675	540	647	788	742	724	623



Generalized sections of coal prospect drill holes.

these points is 107 feet. Number 6 is down the dip from No. 5 and if the dip is as much as five feet per mile (which it probably is not) still the erosional relief is over 100 feet. Numbers 1 and 6 are about 3½ miles apart and located diagonally to the direction of the dip. In these holes the Mississippian surface differs by nearly 200 feet, as its elevation in hole No. 1 is 736 feet above sea level and in No. 6 it is 541 feet. In hole No. 18 the Mississippian rock was not reached, so at this point it must be lower than 537 feet above sea level, but as this location is down the dip from the higher points on the Mississippian surface the importance of this record is somewhat diminished. In the vicinity of the town of Lucas Mississippian rock has been reached about 620 feet above sea level, a comparatively high elevation. Near the center of Monroe county, fifteen miles east of Lucas county, the Mississippian surface is as low as 600 feet above sea level and this is up the dip from the points in northeastern Lucas county.

Even with the large number of drill records available it seems quite unlikely that either the highest or the lowest points on the Mississippian surface should have been found. The conclusion seems justified therefore, that the relief on this buried surface, in Lucas county and in south-central Iowa, is at least 200 feet and may be as much as 250 feet. The Mississippian surface has the characteristics of a mature topography.

Des Moines Surface.—Drill holes 3 and 4 are but one-eighth of a mile apart, yet in that distance the Coal Measures surface changes in elevation by 102 feet. Numbers 15 and 35 are about five miles apart along the strike and between these holes the Pennsylvanian surface differs in altitude by more than 216 feet, from 891 feet above sea level in No. 35 to less than 675 feet in No. 15, where the drill did not completely penetrate the drift. Numbers 15 and 16 are four miles apart in a line diagonal to the strike and the relief on the Des Moines surface between these places is over 263 feet, as this surface was reached at 938 feet above sea level in No. 16 and had not been reached at 675 feet above sea level in No. 15. Furthermore No. 15 is located up the dip relatively to No. 16. Surface exposures of Coal Measures are known between 940 and 950 feet above sea level and as it is very unlikely that the lowest point would have been found in hole No. 15 it seems conclusive that the Coal Measures surface has a mature topography and a relief of at least 265 feet. This surface has an average slope of about 122 feet in a distance of seventeen miles or about seven feet per mile towards the northeast from the center of the county.

The irregular surface between the Coal Measures and the Pleistocene deposits may be due entirely to pre-Pleistocene erosion or it may be the composite result of both pre-Pleistocene and Aftonian erosion. The Nebraskan and Kansan drifts cannot be separated except where their stratigraphic relations to the Nebraskan gumbotil can be determined. It is not certain to which drift such valley fills as those represented in holes 3 and 15 belong. The buried valleys may have been cut in pre-Nebraskan time and the drift may be Nebraskan, or erosion in Aftonian time may have cut through the Nebraskan drift in some places and eroded valleys into the Coal Measures, in which case Kansan drift now fills them. Both tills may be present if the valley existed prior to the Nebraskan ice invasion and was filled with Nebraskan drift and if Aftonian erosion excavated a valley along the same general lines as the pre-Pleistocene valley but did not remove all of the older drift and the Aftonian valley afterward became filled with Kansan drift. Recent erosion, no doubt, exposes in many places sections of till where the lower part is Nebraskan and the upper part is Kansan but the pre-Kansan (Aftonian) erosion had removed all of the Nebraskan gumbotil and now the similar tills lie in contact. In a few places the Nebraskan gumbotil still remains, protected by the overlying Kansan drift.

Thickness of the Des Moines Deposits.—It is apparent from the data given above that the Des Moines series is of greatly differing thickness, owing to the uneven surface on which it was laid down and to the erosion it has suffered subsequent to its deposition. The minimum thickness which has been found at any point in this area is forty-two feet, in hole No. 1. The lowest elevation of the base of the Des Moines series found in the northeastern part of the county was in hole No. 6, where the Mississippian was reached at 541 feet above sea level. In hole No. 16, about 4½ miles west of No. 6 in a line diagonal to the strike, the top of the Coal Measures surface is 938 feet above sea level. The difference between the upper and lower surfaces of the Coal

Measures at these places is 397 feet and very likely represents nearly their greatest thickness in the northeastern part of the county. Near the town of Lucas the Coal Measures are known from hole No. 26 to be over 340 feet thick and the bottom of the hole does not reach the Mississippian surface. The Lower coal in the same vicinity is about 275 feet below the top of the Coal Measures. In other parts of the county the Lower coal horizon is as much as 200 feet above the lowest known elevation of the Mississippian surface. (Compare data in holes 1, 5 and 6 in the table on page 135.) Hence the Des Moines series may be nearly 566 feet thick in the western part of the county.

Thickness of the Pleistocene Deposits.—The present known thickness of the Pleistocene deposits ranges from nothing to more than 226 feet, the latter thickness being found in hole No. 3. The drift is probably thicker in hole No. 15, where the drill penetrated 225 feet of glacial material but did not reach indurated rock. Number 15 is situated in a valley and the curb elevation is 900 feet above sea level. This valley at one time must have been filled with drift up to or nearly to the elevation of the upland, the Kansan plain. This plain, when intact, had an elevation of about 1000 feet above sea level, hence the Pleistocene deposits at this point must once have been fully 325 feet thick. Under the present surfaces of the upland areas, remnants of the once extensive Kansan plain, the Pleistocene deposits are almost nowhere less than 100 feet in thickness.

DETAILED STRATIGRAPHY

MISSISSIPPIAN

The Mississippian system is known only from drill records. No drilling has penetrated very far into these strata, but as the relief on the Mississippian surface is fully 200 feet, at least this thickness of Mississippian rock is known to some extent. Unfortunately, almost no samples or cores have been preserved, so exact identification is impossible. One small length of a drill core in hand is from Pleasant township and was taken between 632½ feet and 617½ feet above sea level. The material is a very hard calcareous white shale or shaly limestone and contains one practically perfect specimen of *Spirifer pellaensis,* index fossil of the Ste. Genevieve or Pella. The Ste. Genevieve formation in

Iowa is known to be only about fifty feet thick and in most places is less than this.

Drill Record No. 1, referred to in table on page 135, shows that the Mississippian rock rises at least 736 feet above sea level. Thus a thickness of fully 100 feet of alternating limestone and sandstone exists above the *Spirifer pellaensis* horizon and below the base of the Des Moines. This cannot all be assigned to the Ste. Genevieve, unless this formation is abnormally thick here.

On the other hand this abnormal thickness, together with the lithologic character of the upper beds, alternating limestones and sandstones, at least suggests the possibility of the presence of some strata of Chester age.

The lowest point at which Mississippian rock has been reached is 541 feet above sea level although other holes go deeper and do not reach it. This depth is seventy-five to one hundred feet below the *Spirifer pellaensis* horizon and this thickness cannot all be assigned to the Ste. Genevieve, so the lowest Mississippian known in the county probably belongs to the St. Louis or the Warsaw, and these limestones are thicker and more massive than the higher beds.

A drilling made near the east side of section 13, Pleasant township, penetrated 65 feet of Mississippian rock. This record is given in full in the appendix (Drill Section No. 2) and in condensed form below.

	THICKNESS Feet	Inches
Surficial material	21	6
Coal Measures	81	3
Mississippian (top at 700 feet above sea level)		
Hard light colored limestone	20	
Soft blue lime shale	1	
Hard light colored sandstone	3	
Hard light colored limestone	17	6
Hard light colored sandstone	6	
Hard light colored limestone	4	6
Hard light colored sandstone	9	
Hard light colored limestone	4	

Another drilling in the southwest corner of section 7, Cedar township, reached the Mississippian at 595 feet above sea level and the drill passed through fifty-five feet of limestone. The record of this hole is given in the appendix as Drill section No. 14. Near the center of section 12, Liberty township, the top of the Mississippian was reached at 614 feet above sea level and the drill passed through eighty-eight feet of alternating beds of limestone and sandstone. The detailed section of this hole is given below.

Drill section No. 31, North of center of section 12, Liberty township.

Curb elevation 832 feet above sea level.

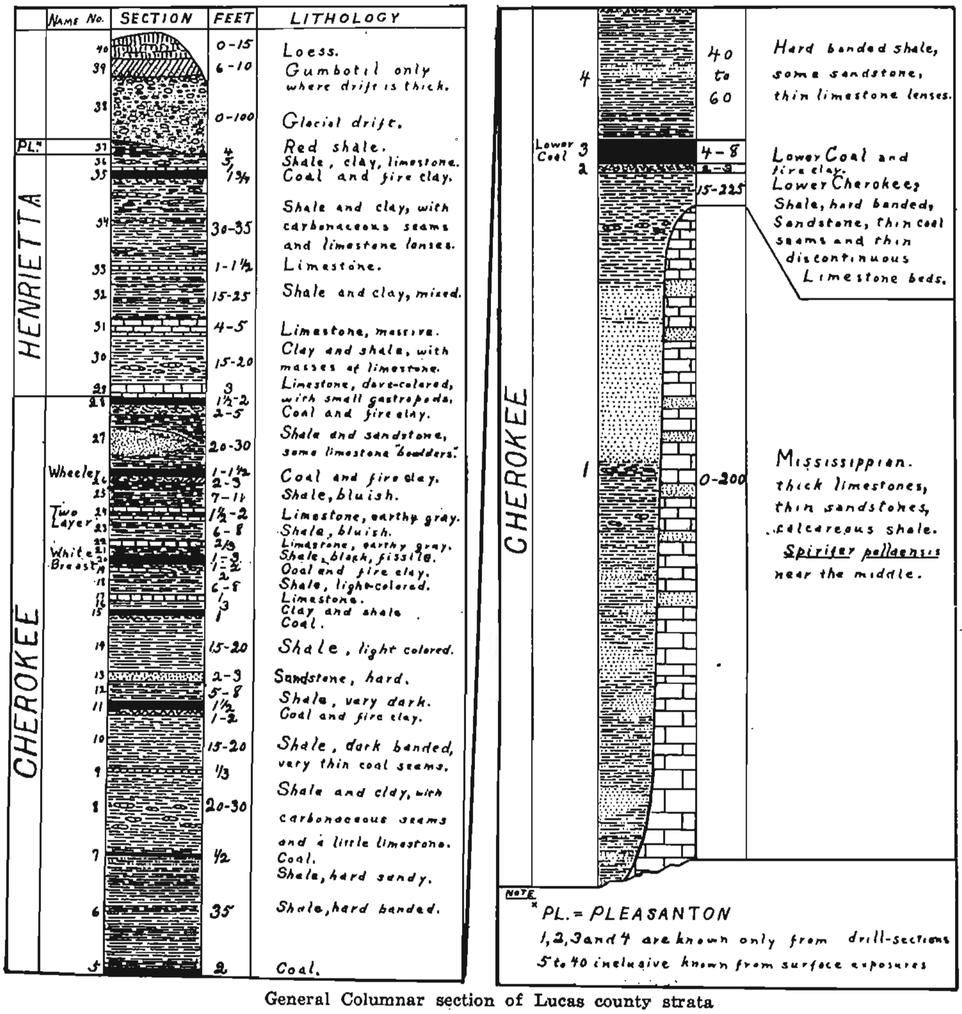
		Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
1.	Soil and clay	12		12	
2.	Sand and gravel	8		20	
3.	Hard blue limestone		6	20	6
4.	Soft black shale	4		24	6
5.	Soft light shale	2	2	26	8
6.	Hard light limestone		7	27	3
7.	Medium soft light sandstone	1	10	29	1
8.	Soft light shale	2	9	31	10
9.	Hard medium light shale	1		32	10
10.	Variegated shale	7	2	40	
11.	Soft light sandstone	7	6	47	6
12.	Variegated shale	2		49	6
13.	Soft light sandstone	9	6	59	
14.	Soft light sandy shale	3		62	
15.	Soft medium dark shale	3	1	65	1
16.	*Coal*		11	66	
17.	Soft light sandy shale	3		69	
18.	Soft black shale	3		72	
19.	Medium soft light sandstone	3		75	
20.	Medium soft dark shale	12	7	87	7
21.	*Coal*	2	6	90	1
22.	Light soft clayey limy shale	6	11	97	
23.	Medium soft medium dark shale	1		98	
24.	Light medium soft sandy shale	6		104	
25.	Soft light sandstone	3		107	
26.	Soft light shale	1		108	
27.	Medium dark soft shale	6		114	
28.	*Coal*	2	2	116	2
29.	Medium soft light shale	3	10	120	
30.	Soft medium dark shale	4		124	
31.	Medium soft medium dark sandy shale	10		134	
32.	Bony *coal*		5	134	5
33.	Medium light medium hard sandy shale	3	7	138	
34.	Medium dark hard sandy shale	3		141	
35.	Hard blue rock	1	6	142	6
36.	Medium dark medium soft shale with light partings and sulfide balls	26	6	169	
37.	Medium dark medium hard shale	16		185	
38.	Medium hard dark shale with quartz bands	6		191	
39.	Dark hard shale	5		196	
40.	Soft light clay shale	3		199	
41.	Dark medium hard shale	4		203	
42.	Light medium soft shale	2		205	
43.	Medium hard dark shale	8		213	
44.	Soft limy shale	5		218	
45.	Hard gray limestone (Mississippian)	6		224	
46.	Hard white limestone	19		243	
47.	Hard dark crystalline limestone	1		244	
48.	Light medium soft sandstone	4		248	
49.	Soft medium light limestone	16		264	
50.	Soft light sandstone	12		276	
51.	Hard light limestone	7		283	
52.	Medium soft light sandstone	15		298	
53.	Hard light sandstone	7		305	
54.	Hard light limestone	1		306	

Total depth 306 feet.
Top of Mississippian 614 feet above sea level.
Bottom of hole 526 feet above sea level.
Thickness of Mississippian penetrated 88 feet.

IOWA GEOLOGICAL SURVEY

PLATE II

COLUMNAR SECTION



General Columnar section of Lucas county strata

DES MOINES

The lower part of the Cherokee formation is known in Lucas county only from drill records made in prospecting for coal. The Cherokee is divisible into two parts on the basis of lithology. The part below the Lower coal is extremely lensy and variable with no very persistent horizons. It is made up largely of thick lenses of sandstone and shale with smaller bodies of limestone and thin coal seams of very small extent. The Lower coal is the lowest horizon that is recognizable as being widespread, even though the coal lenses are not everywhere connected.

The upper part of the Cherokee also is made up of sandstone, shale and thin layers of limestone. The various beds are relatively persistent over quite extensive areas; such beds as the Two Layer limestone and the White Breast coal are excellent horizon markers. The strata are more persistent and less undulatory near the top of the formation. There is no definite lithologic break or discernible unconformity between the Cherokee and the overlying Henrietta formation.

The Henrietta formation is made up of relatively more limestone and very much less coal than the Cherokee, but its strata are no more persistent than are those in the upper part of the Cherokee.

Surface exposures reveal only about the upper one-third of the Cherokee formation. The Henrietta is known from a few fairly good exposures. The Pleasanton, with the exception of the Chariton conglomerate, which is well exposed, is seen in only one or possibly two exposures.

Correlation is possible with certainty only when exposures are very close together. In the detailed sections which follow, certain horizons are named and by comparing adjacent sections the geologic column for Lucas county can be pieced together. The lower sections stratigraphically are in the northeast part of the county and the highest one is in the vicinity of the town of Lucas. All sections are referable to the Columnar Section, which is self-explanatory.

Surface sections are designated by number only (as No. 9); coal prospect hole sections are designated, Drill section No. 10, etc. On the general map the drill section numbers are enclosed in circles.

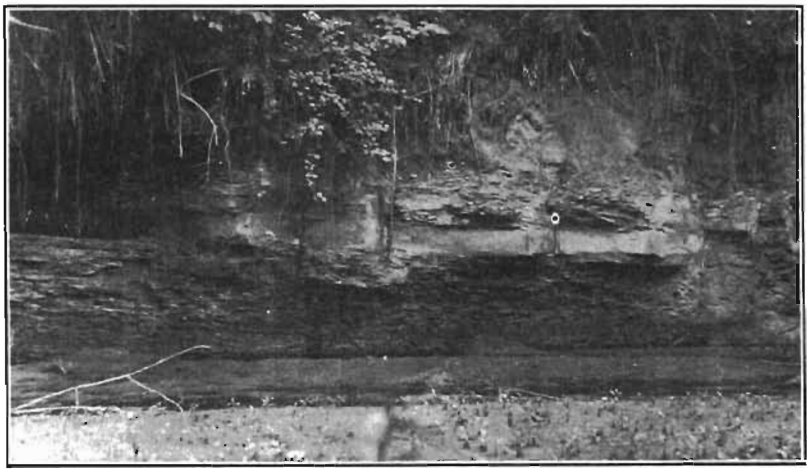


FIG. 15.—An exposure of Cherokee beds in Pleasant township, with a thin sandstone stratum through the middle.

Cherokee Formation.—The term Lower Coal is used as a proper name for the coal horizon known throughout the county by that designation. White Breast is here applied to a coal bed that was first worked along White Breast creek. This coal was called "Panora" in the Iowa Geologic Report of 1870, but this is of doubtful significance and is an inappropriate name for local use. Two Layer limestone is a persistent and characteristic earthy limestone made up of two layers, each four to twelve inches thick, which are separated by two to six inches of shale. It is nearly everywhere seen in the same sections as the White Breast coal. Wheeler coal was named by St. John in the Iowa Geologic Report of 1870 and the name is just as applicable now as it was then and has been retained. These names are suggested for local use only and are used as means of correlation in the sections which follow.

Surface section No. 1. Middle of east side of section 1, Pleasant township.

		FEET	INCHES
16.	Drift and loess mantles upper slope to top of hill	20	
15.	Shales, sandy and light	8	
14.	Clays, light and mixed	7	
13.	*Coal,* soft rotten "blossom" (11 of the Columnar Section) about 840 feet above sea level	1	6
12.	Fire clay	1 to 2	
11.	Clay and shale mixed and variegated	17 to 18	
10.	Limestone, bluish, impure, brittle		4
9.	Shales, dark bluish, in part carbonaceous	2 to 2½	

		Feet	Inches
8.	Clay shales, mixed, limestone nodules........	14	
7.	Shale, dark bluish, carbonaceous...............	1 to 1¼	
6.	Sandstone, soft, light		6
5.	Clay, yellow	1	
4.	Clay, ash-colored like underclay or fire clay	9	
3.	Carbonaceous matter, "coal blossom"....		2 to 3
2.	Shale, hard, banded red and dark, upper 10 feet more sandy	35	
1.	*Coal*, No. 5 of Columnar Section, not exposed but mined at about 765 feet above sea level	2	
	Base 765 feet above sea level.		

Bed No. 1 has been rather extensively mined in this part of the county. It lies forty to eighty feet above the Lower coal, which is mined at Tipperary and Olmitz. The range in the distance of this coal bed above the Lower coal is due to the "rolls and pitches" characteristic of the lower part of the Coal Measures. It is below the coal reported from near the center of section 10, Pleasant township. Numbers 5 to 12 inclusive of the Columnar Section are represented in this surface section.

Other surface sections in this part of Pleasant township are much like the one above but naturally there is considerable variation in minor details from place to place. The coal bed, No. 13 above, outcrops at an elevation of about 865 feet above sea level near the middle of the south side of section 1, Pleasant township, only about three-quarters of a mile southwest of the location of the above section. At the same place another band of carbonaceous matter is exposed about twenty feet below the coal. This second carbonaceous bed probably belongs somewhere in horizon 8 of the Columnar Section. A nine foot bed of light buff sandstone, interbedded with thin clay laminæ, occurs about twelve feet below the carbonaceous stratum. Thus in a comparatively short distance some of the clay and shale beds of Surface section No. 1 are represented by sandstone. Such lateral variation is common in the Des Moines series and especially in the Cherokee formation of this county.

A coal bed eighteen inches thick has been worked to some extent in the vicinity of the southwest corner of section 11, Pleasant township. It seems to be the same horizon as No. 13 in Surface section No. 1, page 144, and No. 11 in the Columnar Section. Its elevation is about 840 to 845 feet above sea level.

Surface section No. 4. Near middle of north side of section 24, Pleasant township.

			FEET
5.	Shales, light, clayey		10
4.	Clay, light ash-colored	4	to 5
3.	Shale, light, sandy	15	to 20
2.	Shale, banded red and black		30
1.	*Coal,* with lime rock "bowlders"	2	to 3
	Base at 780 to 790 feet above sea level.		

This section is similar to that of Surface section No. 1, page 144, in section 1, Pleasant township. The coal bed in this exposure is the same as that mined at or below the creek level in sections 1, 11, 13 and 24, Pleasant township. It is the same horizon as bed No. 1 in Surface section No. 1, and is No. 5 of the Columnar Section.

Coal bed number 13 of Surface section No. 1, page 144, is again exposed in the creek bank a little east of the center of section 10, Pleasant township. Here it is eighteen inches thick and at an elevation of about 840 feet above sea level. This may be the same coal bed worked in the early days at Dale's mine, which was located near this point. The strata at this place are somewhat deformed, being sharply folded downward at the east end of the exposure. The folding is of very small magnitude but because of it, this coal bed has never been successfully mined to any extent in this vicinity.

The base of the above Surface section is two to five feet above the coal bed exposed in the creek bank half a mile east, which is the same as stratum No. 13 in Surface section No. 1, page 144. Strata 2 and 3 above are represented by bed No. 13 in the Columnar Section.

Surface section No. 12. Middle northwest quarter section 10, Pleasant township.

			FEET	INCHES
12.	Shale, badly slumped and covered		10	
11.	*Coal* (White Breast), about 870 feet above sea level		1	6
10.	Fire clay		2	
9.	Limestone, fossiliferous		1	3
8.	Shale, light		7	
7.	Limestone			4
6.	Shale, light and clayey		3	
5.	Shale, carbonaceous, coal blossom, at 850 feet above sea level			9
4.	Shale, badly covered	15	to 20	
3.	Sandstone, thin layered, soft		1	
2.	Sandstone, "cap rock", hard and quartzitic, light gray on fresh surface, uneven thickness		2	
1.	Shale, black, fat		5	
	Base at 825 to 830 feet above sea level.			

Several exposures along Flint creek in the northern and western part of section 16 and in the northeast quarter of section 17, Pleasant township, yield the composite section which follows:

Surface section No. 13.

		FEET	INCHES
13.	Shale, light, sandy, gray and yellowish	10	
12.	*Coal* (Wheeler), 885 to 890 feet above sea level	1	
11.	Fire clay	2 to 3	
10.	Shales, light blue, gritty, with limestone nodules	7 to 8	
9.	Two Layer limestone { Limestone, fossiliferous, earthy, 4 inches; Shale parting, 6 inches; Limestone, fossiliferous, earthy, 8 inches }	1	6
8.	Shales, dark bluish	7	
7.	Limestone, bluish, impure, weathered brown		8
6.	Shale, black, fissile, overlying White Breast coal	3	
5.	*Coal* (White Breast), 860 to 870 feet above sea level	1	
4.	Fire clay	2	
3.	Clay shale, with fossiliferous limestone masses and nodules	6 to 7	
2.	Limestone, impure, brown, fossiliferous, with two inch clay parting in upper part	1	
1.	Shale, carbonaceous, black	2	
	Base about 850 feet above sea level.		

The lower beds of this section are equivalent to the upper beds of Surface section No. 12, page 146. The black fissile shale overlying the White Breast coal is unusually thick in this section. Both the White Breast and Wheeler coals have been mined to some extent in this vicinity. Beds numbered 6 to 13 inclusive in the above section are well exposed at one place in the creek bank near the middle of the northeast quarter of section 17, Pleasant township. This place was visited by St. John in 1867 and the exposure was described by him and was used as one of his type sections.

Near the middle of section 3, Pleasant township, the Wheeler and White Breast coals can again be recognized and the sequence of strata is the same as in the above section except that the White Breast coal and the Two Layer limestone are separated by about eighteen feet of shale instead of ten. The elevation of the White Breast seam at this place is about 850 to 855 feet above sea level, and the Wheeler bed is about twenty-six feet higher. The sequence of strata below the White Breast coal is almost identical with that in other sections already given except that the shale beds are thicker. A coal stratum one foot thick which occurs twenty-eight to thirty feet below the White Breast bed also is exposed in this vicinity. Probably it is the equivalent of bed number five in Surface section No. 12, page 146, but lies at a lower elevation. This bed of coal is separated from a still lower eight inch bed by about four feet of light colored shale and fire clay. The strata exposed in this locality lie at a somewhat lower elevation than they do a mile or more farther south and southeast. Thus the strata seem to have a local northwesterly dip in this part of the county.

The thin seam of coal outcropping at about 870 feet above sea level a little north of the middle of the west side of section 21, Pleasant township, may be the White Breast bed.

The White Breast coal, characteristically overlain by one foot of carbonaceous fissile shale which in turn is covered by a thin layer of earthy gray fossiliferous limestone, outcrops near the middle of the north side of section 5, Pleasant township. The above limestone, which is about ten inches thick, is overlain by seven and one-half feet of bluish dark shale and this is followed by the Two Layer limestone, which has an additional clay parting near the top. The beds exposed here duplicate almost exactly beds 3 to 10 inclusive, previously given in Surface section No. 13, page 147. However, at this place the White Breast coal bed is at an elevation of about 900 feet above sea level, somewhat higher than should be expected.

Surface section No. 19. Southeast quarter, section 7, Cedar township.

	FEET	INCHES
6. Shale and drift (covered)		
5. Clay, yellow, with 6 inch impure limestone band	1	
4. Shale, fissile, black, hard	1½ to 2	
3. Shale, carbonaceous	2½ to 3	
2. Coal and brittle shale (White Breast)		10
1. Shale and clay, light colored	8 to 10	
Base at about 860 feet above sea level.		

The White Breast coal has been mined in this vicinity. The Wheeler coal outcrops at about 895 feet above sea level, about one and one-half miles northwest of the location of the above section, near the middle of the north side of section 12, Lincoln township. It is underlain and overlain by light colored shales which are poorly exposed. The beds exposed at this place are equivalent to and seem to be almost identical with part of 10, all of 11 and 12 and part of 13 in Surface section 13, page 147. The Wheeler coal in this exposure is in the normal stratigraphic position relative to the White Breast bed exposed along North Cedar creek one and one-half miles to the southeast.

The drillings in the northeast part of the county are, for the most part, drilled from valley bottoms and the elevations of their curbs are in many cases as low as the bases of the surface sections. Drill sections can be correlated with a fair degree of accuracy, using the Lower Coal horizon as a datum plane. Drill section No. 7, which follows, represents quite typically the deeper strata in the northeast part of the county. Bed No. 10 in this hole is stratum No. 13 of Surface section No. 1, page 144. The reader should bear in mind that in most cases the Surface sections are given in greater detail than the Drill sections.

Drill section No. 7. Three hundred fifty feet east of middle of west side of southwest quarter of section 22, Pleasant township.

Curb Elevation 898 feet above sea level.

		THICKNESS		DEPTH	
		Ft.	*In.*	*Ft.*	*In.*
1.	Soil	12		12	
2.	Sand and clay	30		42	
3.	Soft light clay shale	7		49	
4.	Hard limestone	1		50	
5.	Soft light shale	4		54	
6.	Soft variegated shale	6		60	
7.	Soft light shale	2		62	
8.	Hard rock		6	62	6
9.	Medium soft dark shale	3	6	66	
10.	*Coal* (No. 11 of Columnar Section)	1		67	
11.	Medium light sandy shale	14		81	
12.	Medium soft variegated shale	7		88	
13.	Medium hard dark shale	2		90	
14.	Medium soft medium light shale	8	3	98	3
15.	*Coal* (No. 7 of Columnar Section)		9	99	
16.	Medium hard dark streaked shale	70		169	
17.	Hard medium light banded shale	14		183	
18.	Carbonaceous shale	1		184	
19.	*Coal* (Lower)	6	2	190	2
20.	Medium hard medium dark shale		10	191	
21.	Medium hard light fire clay	4		195	

Total depth 195 feet.
Top of Lower coal (19) 714 feet above sea level.
Bottom of hole 703 feet above sea level.

Drill section No. 11, located near the center of section 32, Pleasant township, and given in the Appendix, page 225, almost duplicates hole No. 7, except that the different strata show some variation in thickness and the coal beds are at slightly different elevations. Drill section No. 17, located near the center of the southeast quarter of section 12, Lincoln township, is quite typical of records from this vicinity.

Drill section No. 17. Near center of southeast quarter of section 12, Lincoln township.

Curb Elevation 1010 feet above sea level.

		THICKNESS		DEPTH	
		Ft.	*In.*	*Ft.*	*In.*
1.	Surface soil, loess, gumbotil	24		24	
2.	Sand and clay, some bowlders	68		92	
3.	Sand	23		115	
4.	Blue clay	14		129	
5.	Shale, medium hard, variegated	3		132	
6.	Shale, medium dark	6		138	
7.	Shale, hard, dark, "carbonaceous"	5		143	
8.	*Coal* (may be White Breast)		9	143	9
9.	Shale, medium hard and light	19	3	163	
10.	Shale, hard and medium dark	4		167	
11.	Blue rock, hard	3		170	
12.	Shale, hard and dark	4		174	
13.	Blue rock, hard	1		175	
14.	Shale, hard and dark	15		190	
15.	*Coal* (No. 11 of Columnar Section)	1		191	
16.	Shale, medium soft and light	9		200	
17.	Sandstone	3		203	
18.	Sandy shale, hard and light	4		207	
19.	Shale, medium hard and medium dark	7		214	
20.	Shale, medium hard and medium light	11		225	
21.	Shale, hard and dark	3		228	
22.	*Coal* (No. 7 of Columnar Section)	1		229	
23.	Shale, hard, medium dark	62		291	
24.	*Coal* (Lower)	5	2	296	2
25.	Sandstone, soft and light	2	10	299	

Total depth 299 feet.
Top of Lower coal 719 feet above sea level.
Bottom of hole 711 feet above sea level.

Coal bed No. 15 of the above section may be No. 11 of the Columnar Section. Number 8 in this hole is 857 feet above sea level and this is about the same as the elevation of the White Breast coal along North Cedar creek about a mile farther east. It seems quite probable that bed No. 8 is the same as the White Breast coal described in Surface section No. 19, page 148. Coal bed number 5 of the Columnar Section, which is mined at several places in the northeastern part of Pleasant township, does not seem to occur in the vicinity of holes No. 7 or No. 17, but it does appear in a hole drilled near the southwest corner of section 36, English township. The record of this hole is given in the Appendix as Drill section No. 32.

Drill section No. 14, given in the appendix, page 226, is the record of a hole put down a little east of the northwest corner of section 7, Cedar township. At a depth of 385 feet the Mississippian limestone was reached (959 feet above sea level) and not a single workable coal bed was passed through. This hole in relation to others previously given illustrates the fact of the lenslike character of the coal beds. Another drilling, Drill section No. 16, given in the appendix, page 227, and located near the southeast corner of section 2, Lincoln township, penetrated to a depth of 376 feet and here the Lower coal horizon together with over 100 feet of strata above and below it are entirely replaced by light colored sandstone.

The exposures of Coal Measures in the eastern part of English township along English creek essentially duplicate exposures farther east. This fact is evident when the surface section which follows, taken from the northeastern part of section 1, English township, is compared with Surface sections 12 and 13, given on pages 146 and 147 respectively. The elevation above sea level of the corresponding beds is a little higher in English township than would normally be expected.

Surface section No. 21. Middle of north side of section 1, English township.

		FEET	INCHES
14.	Glacial drift	15	
13.	Shale, light	10	
12.	*Coal* (Wheeler)	1	
11.	Fire clay	1	6
10.	Clayey shale, yellowish	6	
9.	Limestone, in two layers, Two Layer limestone	3	
8.	Shale, bluish	10	
7.	*Carbonaceous material* (White Breast coal)		10
6.	Clay and shale, mixed, varicolored	21	
5.	Shale, variegated, limestone nodules in upper 2 feet	10	
4.	Shale, blue-gray	4	
3.	Carbonaceous band		4
2.	Clay, mixed, varicolored and in part sandy	12	6
1.	Shale, bluish to gray, becoming sandy at top	12	
	Base at 840 feet above sea level.		

Bed No. 7, the White Breast coal, is not typically exposed in this section but this horizon is recognizable as such in the vicinity. The impure buff-colored limestone that usually overlies it is absent but is well developed a short distance away along the creek. This limestone "cap rock" is not continuous in this locality but is represented by a stratum of "bowlders" typical of the margin of a limestone lens. The White Breast coal again outcrops in the southeast quarter of section 2, English township, about 875 feet above sea level.

The White Breast and Wheeler coals, separated by about twenty feet of shale beds and the Two Layer limestone, which is typically developed, are well exposed in the southeast quarter of section 11, English township. The characteristic thin limestone "cap rock" overlies the White Breast bed at this place. The elevation of the White Breast stratum is about 885 feet above sea level. In addition a higher coal horizon occurs eighteen to twenty feet above the Wheeler coal. Both the White Breast and Wheeler coals have been mined in this locality.

Surface section No. 24, which follows, illustrates very typically the relations of the White Breast and Wheeler coal beds. Where these two coal beds are exposed together the character of the intervening strata and their sequence are almost everywhere the same and the beds are widespread over much of the county. The beds represented in this section are the best horizon markers in the geologic column of Lucas county. This exposure was described by St. John.

Surface section No. 24. Northeast quarter section 15, English township.

		FEET	INCHES
10.	Shale, sandy	25 to 30	
9.	*Coal* (Wheeler)	1	
8.	Fire clay	1	
7.	Shale, light yellowish, poorly bedded	15	
6.	Limestone, Two Layer	2	
5.	Shale, light bluish and yellow	10	
4.	Limestone, bluish gray		6
3.	Shale, black, fissile	1	6
2.	*Coal* (White Breast)		12 to 15
1.	Shale, mixed, limestone nodules 4 feet from top	12	
	Base at 890 feet above sea level.		

The White Breast coal has been mined in this vicinity. A four foot bed of white limestone is exposed at the same level as the White Breast coal, which occurs a short distance from the limestone exposure, along Long Branch creek near the middle of the east side of section 4, English township. This limestone is believed to be bed No. 31 of the Columnar Section and is again referred to on page 157.

The upper English creek valley area has been quite thoroughly prospected for coal and a number of drill holes have been made. In this locality the Lower coal is from four to seven feet thick and of excellent quality. Drill section No. 35, which follows, is typical of records from this area. It is quite similar to Drill sections 7 and 17 previously given on pages 149 and 150. Other sections from this field are given in the Appendix (Nos. 34, 37 and 38). The main shaft of Mine No. 4 of the Central Iowa Fuel Company was sunk on this hole.

Drill section No. 35. (Main shaft of No. 4 mine sunk on this hole.) West middle of northwest quarter, section 24, English township.

Curb elevation 1004 feet above sea level.

		THICKNESS Ft.	THICKNESS In.	DEPTH Ft.	DEPTH In.
1.	Soil and loess	18		18	
2.	Yellow clay	23		41	
3.	Gravel	2		45	
4.	Blue clay	4		49	
5.	Gravel	2		51	
6.	Blue clay	3		54	
7.	Gravel	1		55	
8.	Blue clay	8		63	
9.	Blue clay, sand and gravel	15		78	
10.	Sand and gravel	4		82	
11.	Blue clay	5		87	
12.	Gravel	2		89	
13.	Blue clay	20		109	
14.	Yellow clay and sand	4		113	
15.	Shale, light	5		118	
16.	Shale, soft, gray	6	6	124	6
17.	*Coal* (may be White Breast horizon)		6	125	
18.	Shale, soft, light and dark banded	54		179	
19.	Rock, hard, gray	1		180	
20.	Shale, hard, dark	3		183	
21.	*Coal* (may be No. 11 of Columnar Section)	1		184	
22.	Shale, medium hard, light	6		190	
23.	Shale, soft, light	3		193	
24.	Shale, hard, light, sandy	1		194	
25.	Shale, medium hard, light	15		209	
26.	*Coal* (may be 7 of Columnar Section)		8	209	8
27.	Shale, hard, gray	10	4	220	
28.	Shale, gray, sandy	12		232	
29.	Sandstone, soft	4		236	
30.	Shale, medium hard and medium dark	49	4	285	4
31.	"Shoddy" top		8	286	
32.	*Coal* (Lower)	6	9	292	9
33.	False bottom		3	293	
34.	Fire clay, light	1		294	

Total depth 294 feet.
Bottom of hole 710 feet above sea level.
Top of Lower coal 718 feet above sea level.

At a point three-eighths of a mile northeast of this drilling a fifteen inch coal seam appears in the road above the highest coal in this log (No. 17). It may be the Wheeler bed.

Surface section No. 28. General vicinity of northeast corner of Liberty township, along White Breast creek.

		FEET	INCHES
14.	Three feet covered, drift above		
13.	Sandstone, soft, no fossils	5	6
12.	Clay or silt, sandy	2	6

11.	Shale, bluish, grading up into 3 feet of clay		12	
10.	*Coal* (No. 28 of Columnar Section)		1	
9.	Sandstone and sandy shale (plant fossils in upper part)		15	
8.	Shale and clay, sandy		20	
7.	*Coal* (Wheeler)		1	10
6.	Clay, blue, and light fire clay		3	
5.	Limestone, earthy, fossiliferous	Two layer limestone		6
4.	Clay shale, fossiliferous			6
3.	Limestone, earthy, fossiliferous			8
2.	Clay shale, blue-gray		3	
1.	Shale, sandy, buff		9	
	Base at 835 feet above sea level.			

The White Breast coal is known to occur a few feet below the base of the above section and it outcrops in the bed of White Breast creek in the northeast quarter of section 11, Liberty township. Number 7 in the above section is the Wheeler coal and number 10 is a higher coal that is well developed farther south, where it is overlain by a bluish gray cap rock limestone. Another coal bed, fourteen inches to two feet thick, which lies below the Two Layer limestone, appears in outcrops a mile to a mile and a half to the northwest. There seem, then, to be four coal beds represented in the vicinity of Surface section No. 28. The strata here have a dip to the northwest of about twenty to twenty-five feet per mile and this structural feature brings the Two Layer limestone up much higher in section No. 27, which follows. Drill section No. 31, given on page 141, shows the relations of the deeper strata.

Surface section No. 27. General vicinity of the middle of the west side of English township, along Little White Breast creek.

		FEET	INCHES
15.	Glacial drift, reddish and sandy		
14.	Shale, light, calcareous	5 to 8	
13.	*Coal* (No. 28 of Columnar Section)	1	3
12.	Fire clay	1	6
11.	Shale and sandstone	7	
10.	Clay and shale, light and sandy	11	
9.	*Coal* (Wheeler)		8 to 12
8.	Clay, yellow, grades into light fire clay	6	
7.	Two Layer limestone	1	6
6.	Shale, light gray	7	
5.	*Coal*, poor quality (White Breast)	1	
4.	Shale, light, grading into fire clay	8	
3.	Sandstone, in part calcareous	1 to 1½	
2.	Shale, sandy and in part calcareous, with fossils	2	
1.	Shale, light blue to gray	5	
	Base at 860 feet above sea level.		

The coal, No. 13 above, is the same as bed No. 10 in Surface section No. 28. This upper coal is said to be overlain in most places by a two foot layer of hard "cap rock" limestone. The sandiness of the underlying beds also is typical for these horizons. A similar sequence, with the "cap rock" limestone above the coal, is conspicuous in Swede Hollow, four and a half miles to the southwest. Both bed No. 9 and bed No. 13 of this section have been mined along Little White Breast creek.

The Wheeler coal and the coal next above it in the preceding section (No. 27) also have been worked to a considerable extent in the southwest corner of English township, in the northwest corner of Lincoln township and in section 1 of White Breast township, along Little White Breast creek and some of its tributaries. These coal beds are separated by sandy beds twenty to thirty feet thick and the upper bed is overlain by the "cap rock" limestone. It should be noted that the "lower" surface coal of this vicinity is not the White Breast coal of other localities but is the Wheeler bed, which lies above the Two Layer limestone. The stratigraphic relations of these beds have been shown in Surface sections No. 24, No. 28, No. 27, and in the Columnar Section. These relations are essentially the same for the northwest part of Lincoln township.

Near the middle of the west side and in the southwest quarter of section 4, Lincoln township, the Wheeler coal, eighteen inches to two feet thick, again outcrops at an elevation of about 900 feet above sea level, nearly the same as in Surface section No. 27. A coal that corresponds to bed No. 13 of Surface section No. 27 is known in this vicinity also. It is underlain by sandy strata and overlain by mixed shales that are not well exposed, but the capping limestone seems to be absent.

The unexposed strata of the vicinity along Little White Breast creek about three and one-half miles northeast of Chariton are quite typically shown in Drill section No. 19, which follows. Other drill records from this locality are recorded in the appendix as Drill sections 18, 20, 21 and 39. This section is the record of the hole on which the main shaft of the "Old No. 1" mine of the Central Iowa Fuel Company was sunk. The Lower coal was well developed in this basin but has now been "mined out." On account of the variability of the Coal Measures strata it is difficult to correlate all of the horizons, especially where surface exposures are few and shallow as they are in this vicinity. However, it seems quite probable that bed No. 7 of this section is the Wheeler coal horizon.

Drill section No. 19. Inland shaft or "Old No. 1", northwest part of the northwest quarter of section 9, Lincoln township.

Curb elevation 925 feet above sea level.

		THICKNESS Ft.	THICKNESS In.	DEPTH Ft.	DEPTH In.
1.	Soil and clay	14		14	
2.	Clay and sandy clay	8		22	
3.	Sand and sandy clay	10	6	32	6
4.	Clay, sand and bowlders	2		34	6
5.	Shale, light, soft and seamy	7		41	6
6.	Shale, dark, soft and seamy	11		52	6
7.	*Coal*, good (may be Wheeler bed)	2		54	6
8.	Fire clay	2		56	6
9.	Fire clay, hard and sandy	3		59	6
10.	Sandstone	2		61	6
11.	Limestone	1		62	6
12.	Light sandstone	2		64	6
13.	Shale, light and sandy	11		75	6
14.	Shale, variegated	8	6	84	
15.	Shale, light	6		90	
16.	Shale, black	8		98	
17.	*Coal*	1		99	
18.	Fire clay	3		102	
19.	Shale, light	4		106	
20.	Shale, dark and hard	10		116	
21.	Limestone		6	116	6
22.	*Coal*	1	6	118	
23.	Fire clay, dark and hard	7		125	
24.	Sandstone, light and hard	3		128	
25.	Shale, light and hard	2		130	
26.	Shale, dark and medium hard	15		145	
27.	*Coal*		3	145	3
28.	Shale, dark and hard	1		146	3
29.	Carbonaceous shale		6	146	9
30.	Fire clay, hard	6	3	153	
31.	Sandstone, light and medium hard	31		184	
32.	Shale, dark and hard	10		194	
33.	Sandstone	2		196	
34.	Shale, medium dark and medium hard	43		239	
35.	*Coal* (Lower)	7		246	
36.	Fire clay	3		249	
37.	Sandstone, hard	9		258	

Total depth 258 feet.
Top of Lower coal 686 feet above sea level.
Bottom of hole 667 feet above sea level.

Surface section No. 32. General vicinity of the upper part of Little White Breast creek northeast of Chariton.

		FEET	INCHES
9.	Shale (covered) and drift	60	
8.	Limestone, very pure and white in places and divided by clay and sand partings in other places	4	6

7.	Shale, bluish in part, sandy, uneven thickness	9	
6.	Limestone, discontinuous		8
5.	Shale and clay (covered)	2 or 3	
4.	*Coal* (bed 28 in Columnar Section)	1	
3.	Shale, light, mixed, in part sandy	12 to 15	
2.	*Coal* (Wheeler, 900 feet above sea level)	1	9
1.	Shale, light, mixed, in part sandy	15	
	Base at 885 feet above sea level.		

There is little doubt that No. 2 above is the Wheeler coal of other sections. Bed No. 4 is another coal horizon of rather limited extent. These two coals have been thought to be the White Breast and Wheeler, but the White Breast probably is forty to fifty feet below the base of this section and is not exposed. The second coal (No. 4) in this section also has over it in places an eight inch cap-rock limestone which is thought to be the basal member of the Henrietta formation. Probably it is the coal that outcrops at the Chariton water reservoir spillway, about 915 feet above sea level. At this latter place it is one and a half to two feet thick and is underlain by fire clay and sandy shale which grades into a fairly resistant sandstone farther north. The overlying shales also are sandy. Both coals of this section have been mined along Little White Breast creek.

The relatively thick limestone (No. 8) of this vicinity is of very good quality and is white in color. It was quite extensively quarried in an earlier day in the southeast quarter of section 16, Lincoln township. The same limestone is poorly exposed in the southeast corner of section 16, English township. In this place it is in the proper stratigraphic relation to the Wheeler and White Breast coal beds, which are shown in a surface exposure a mile to the northeast, described in section No. 24, page 152. It is known to be present also in the east part of section 4, English township, where it was formerly exposed in the Smith quarries on Long Branch creek, about 930 feet above sea level, which is too low. These quarries were open at the time of St. John's visit in 1867 and he noted the anomalous position of these beds.[23] St. John thought they had slumped from a higher position and this seems to be the correct interpretation, as the White Breast coal occurs only a few rods distant at nearly the same level as the limestone.

A four foot bed of white limestone, which was formerly quar-

23 The Geology of Iowa (1870), vol. II, p. 90.

ried, is exposed about 910 feet above sea level, at a few places in Washington township, along Chariton river and its tributaries. A coal bed has been worked a few feet above the limestone and another bed several feet below it, but these beds are not now exposed. This rock may be the same as the relatively thick limestone, No. 31 of the Columnar Section, occurring northeast of Chariton and at other points above noted. This bed has been reported from the northeast part of Wayne county. It is believed to be Henrietta in age.

The only drill section in hand from the southeast part of the county is given below. Sandstone and sandy shale beds are more conspicuous in this section than in sections from other places in the county. Very little coal seems to have been formed in this vicinity as no prospecting has revealed a workable bed.

Drill section No. 40. Northwest corner of the northeast quarter of section 12, Benton township.

Curb elevation 979 feet above sea level.

		THICKNESS		DEPTH	
		Ft.	*In.*	*Ft.*	*In.*
1.	Soil	7		7	
2.	Blue clay	5		12	
3.	Sand	5		17	
4.	Sand and clay	10		27	
5.	Dark blue clay	21		48	
6.	Sand and gravel	6		54	
7.	Light clay	40		94	
8.	Yellow clay	16		110	
9.	Light shale	2		112	
10.	Light shale	23		135	
11.	Dark sandy shale	8		143	
12.	Gray limestone (may be about the horizon of the Two Layer limestone)	1	4	144	4
13.	Dark sandy shale	3	8	148	
14.	Soft light sandstone	36		184	
15.	Sandstone	16		200	
16.	*Coal* (may be about the horizon of No. 11 of Columnar Section)		3	200	3
17.	Limestone	3	9	204	
18.	Hard sandstone	1		205	
19.	Soft gray sandstone	19		224	
20.	Sandstone	32		256	
21.	Dark shale	4		260	
22.	Light shale	2	6	262	6
23.	Bone *coal* (about horizon No. 5 of Columnar Section)	1	6	264	
24.	Fire clay	2		266	
25.	Dark sandstone	24		290	
26.	Sandstone	18		308	
27.	Limestone	4	7	312	7
28.	*Coal* (Lower coal horizon)		3	312	10
29.	Fire clay	1	2	314	
30.	Limy shale	4	6	318	6
31.	Dark shale	4	6	323	

Total depth 323 feet.
Bottom of hole 656 feet above sea level.

No surface exposures are known in the southwestern part of the county. A number of drillings have been made southwest of the city of Chariton and Drill section No. 27, which follows, represents the sequence of strata for the area. The Lower coal occurs in this district but it has a wide range in elevation and it has not been mined here. In the section below its elevation is 693 feet above sea level and in another hole (No. 23, appendix) about two and a quarter miles east and a little north the elevation of the Lower coal was only 654 feet above sea level. In a third hole (No. 24, appendix) located in the southeast quarter of section 24, White Breast township, the lower coal is 668 feet above sea level. It occurs at an elevation of 670 feet above sea level in a hole drilled about a mile southwest of hole No. 24. In the same hole (No. 26 of the appendix) the drill penetrated 110 feet of strata below the Lower coal horizon, which in this hole was only six inches thick, and fully two-thirds of these beds were sandstone while the remainder were sandy shales. This range in elevation and the similar range in thickness of the Lower coal are not unusual. The differences in elevation of the Lower coal bed are quite large in all of the mines and are known to be more than forty feet in some. This is discussed in greater detail on pages 183 to 186 inclusive.

Drill section No. 27. Middle east half section 34, White Breast township.

Curb elevation 1012 feet above sea level.

		THICKNESS		DEPTH	
		Ft.	*In.*	*Ft.*	*In.*
1.	Soil and clay, drift in part	48		48	
2.	Sandy drift	30		78	
3.	Medium hard light shale	19		97	
4.	Hard dark shale	1	6	98	6
5.	Hard medium light shale	17	6	116	
6.	*Coal*	1		117	
7.	Soft medium light shale	7		124	
8.	Hard medium light shale with sand streaks	4		128	
9.	Hard dark banded shale	6		134	
10.	*Coal*	1	6	135	6
11.	Soft light shale	8	6	144	
12.	Hard limestone	2		146	
13.	Medium soft medium light shale	5		151	
14.	Hard dark shale	1		152	
15.	Soft light shale	5		157	
16.	Medium hard medium light sandy shale	9		166	
17.	Medium hard medium dark shale	2		168	
18.	Variegated shale	8		176	
19.	Soft medium light shale	7		183	
20.	Hard dark shale	3		186	
21.	*Coal* (White Breast ?)	1		187	
22.	Soft medium light shale	6		193	

23.	Limestone (may be horizon 17 of Columnar Section)	1		194	
24.	Medium hard variegated shale	2		196	
25.	Hard medium light shale	5		201	
26.	Hard variegated shale	3		204	
27.	Hard limestone	1	7	205	7
28.	Medium hard light shale	1	5	207	
29.	Hard dark shale	2		209	
30.	*Coal*, rotten (about No. 11 of Columnar Section)	1		210	
31.	Medium soft medium dark shale	4		214	
32.	Medium soft light shale	3		217	
33.	Medium soft variegated shale	3		220	
34.	Medium light medium hard shale	8		228	
35.	Hard medium dark shale	4		232	
36.	Sandstone	6		238	
37.	Hard medium light shale	3		241	
38.	Sandstone	5		246	
39.	Hard dark shale	4		250	
40.	*Coal* (may be about horizon No. 7 of Columnar Section)		6	250	6
41.	Soft light sandstone	25	6	276	
42.	Hard medium dark shale	43	6	319	6
43.	*Coal* (Lower)	6	3	325	9
44.	Sandy fire clay	4	3	330	

Total depth 330 feet.
Top of coal (43) 693 feet above sea level.
Bottom of hole 682 feet above sea level.

Good Coal Measures exposures occur along White Breast creek from the south part of Liberty township in the vicinity of "Wheelers" bridge to the town of Lucas, and also in Swede Hollow, a small tributary of White Breast valley. The exposures in this locality essentially duplicate exposures already described from English, Pleasant and Lincoln townships. Strata exposed

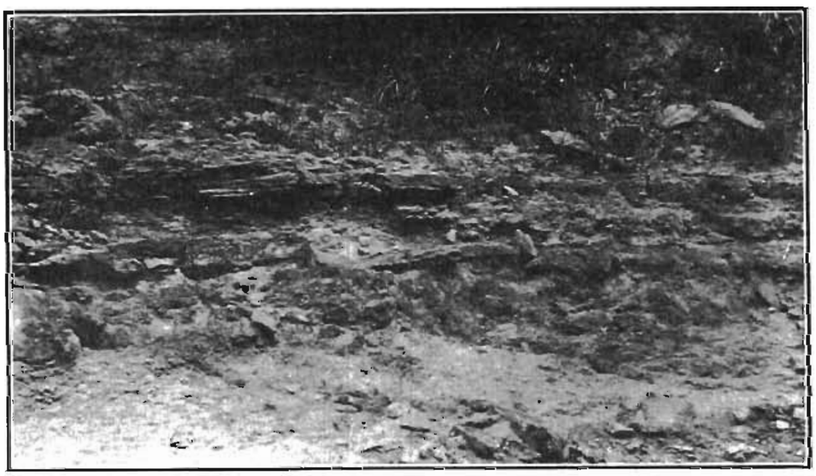


Fig. 16.—Strata of part of exposure north of Wheeler's bridge.

in outcrops in the south part of the southeast quarter of section 28, Liberty township, are almost exactly like beds 1 to 5 inclusive described in Surface section No. 13, page 147. From this point southwest along White Breast creek the strata have an appreciable southwestward dip.

Surface section No. 36. South of Wheeler's bridge near the middle of section 33, Liberty township.

		FEET	INCHES
14.	Clay, covered		
13.	*Coal* (Wheeler)	1	6
12.	Shale, light, yellowish and bluish	6	
11.	Limestone, fossiliferous } Two layer limestone		7
10.	Shale, greenish to gray } Two layer limestone		4
9.	Limestone, fossiliferous } Two layer limestone		13
8.	Clay shale, yellow	1	6
7.	Shale, light bluish gray	4	6
6.	Shale, dark, carbonaceous	2	
5.	Limestone, earthy and fossiliferous		8
4.	Shale, fissile, black, hard "shoddy top"		12 to 18
3.	*Coal* (White Breast)		15 to 18
2.	Shale, bluish and yellowish	3	
1.	Shale, gray, hard and calcareous with nodules	2	
	Base at 830 feet above sea level (water level).		

Surface section No. 36 is the type section from which the White Breast coal has been named by the writer. It was to beds numbered 9, 10 and 11 in this section that the writer first applied the name Two Layer limestone. It is persistent over much of the county where exposures are known, as has been seen from such surface sections as Nos. 13, page 147, 21, page 151, 24, page 152, 28, page 153, 27, page 154. The Wheeler coal received its name

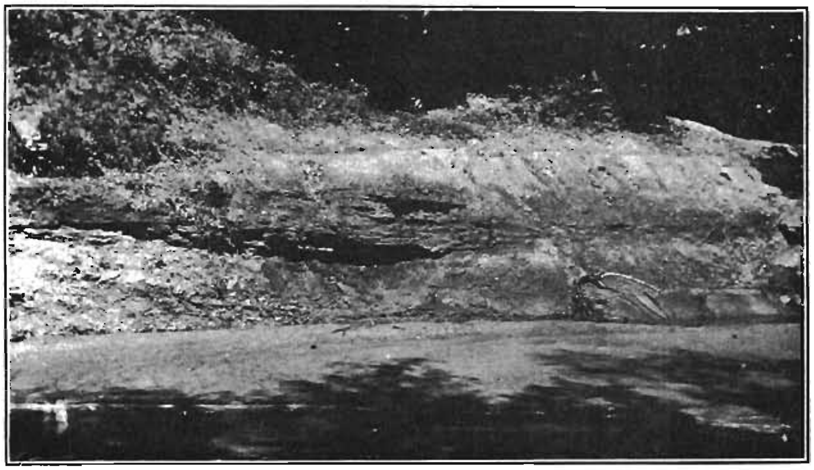


FIG. 17.—Typical Coal Measures exposure in Swede Hollow.

also from this section. The term Wheeler, applied by St. John, has been retained because of its occurrence near "Wheeler's bridge" in section 33, Liberty township. One-half mile southwest of the location of Surface section No. 36, along White Breast creek, the Wheeler coal seam, two feet thick, outcrops eleven feet above the Two Layer limestone.

Henrietta Formation.—In Swede Hollow, south middle of Liberty and north middle of White Breast townships, a higher coal outcrops and has been quite extensively mined. It occurs twenty to thirty-five feet above the Two Layer limestone. The intervening beds are made up of shales and clays that grade into sandstone locally. The Wheeler coal does not seem to have been developed here and does not outcrop in Swede Hollow. The sandstone is in places as much as twelve feet thick and at other points only a few rods distant it is less than one foot thick. In the section which follows (No. 37) the coal (No. 5) is thought to be the equivalent of coal No. 4 in Surface section No. 32 on Little White Breast creek (see page 156).

FIG. 18.—Sandstone in Swede Hollow.

Surface section No. 37. Near middle of northeast quarter section 3, White Breast township.

		FEET
10.	Drift (to the upland)	120
9.	Shale, poorly exposed	10
8.	Limestone, blue-gray, no fossils	1
7.	Shale, poorly exposed	15
6.	Limestone, dark gray or dove-colored, massive, crowded with small gastropod shells	2 to 3
5.	*Coal* (Bed 28 in Columnar Section and top of Cherokee formation)	1½
4.	Clay and fire clay	5
3.	Sandstone, thin bedded	1

2.	Sandstone, heavy, cross-bedded	3	
1.	Shale, dark (may be horizon of Wheeler coal)	4	
	Base at 860 feet above sea level.		

In this vicinity the coal (bed No. 5) is characteristically overlain by the heavy "cap rock" limestone and is quite undulatory. The limestone No. 6 is divided near its middle in some places by a thin clay parting. This is very probably the basal Henrietta member (basal Fort Scott). It contains an abundance of several kinds of small gastropod shells as well as other fossils.

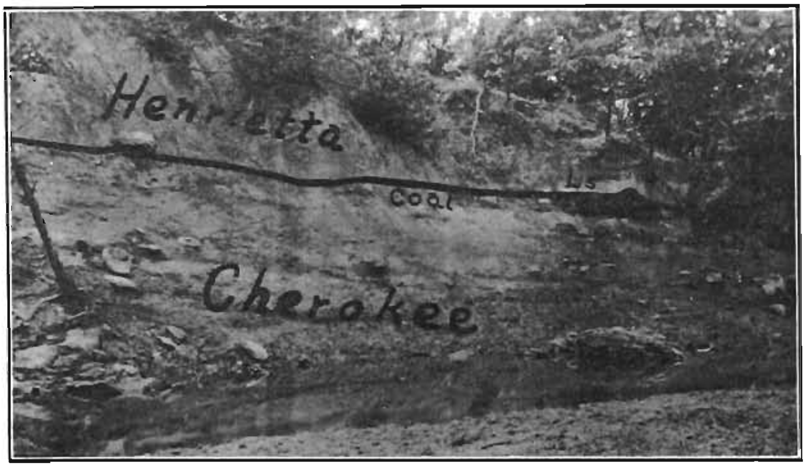


FIG. 19.—Contact of Cherokee and Henrietta formations in southeast quarter of section 5, White Breast township.

The same coal bed with its cap rock limestone is well exposed near the middle of the southeast quarter of section 5, White Breast township. The shale in the lower part of this exposure contains many large limestone "bowlders", which are in reality true septaria. Septaria occur at many places in the county and at many horizons but nowhere else are there as many nor as large ones as in this exposure.

Surface section No. 39. General vicinity of sections 16 and 17, White Breast township.

		FEET	INCHES
15.	Shale, covered	2	
14.	Limestone, hard, fossiliferous, weathers earthy	1	
13.	*Coal*, shaly, bed No. 35 of Columnar Section (about 930 feet above sea level)		22
12.	Shale and clay, variegated, with limestone bands in places	18 to 20	
11.	Shale, carbonaceous, black, slaty, lower		

	part is calcareous and fossiliferous and dips southwest about 7°	3	
10.	Shale, gray, blue and yellowish, upper part has limestone nodules and some carbon	5 to 7	
9.	Clay and shale, mottled	5	
8.	Limestone band, hard, gray, fossiliferous		6 to 12
7.	Shale, bluish, not well exposed	7	
6.	Shale, bluish, in part sandy, molds of fossils	1	
5.	Shale, light bluish, bedded, limestone nodules at top	4	
4.	Shale, carbonaceous		6
3.	Shale, bluish and yellow, poorly bedded	5	
2.	Shale, carbonaceous and black	1	
1.	Clay, ocher-colored and bluish, upper part contains limestone nodules	4	
	Base at 890 feet above sea level.		

This section, which is not seen in its entirety at any one exposure, so far as known, represents the only good outcrops in Lucas county of these horizons, which are thought to be the middle and upper parts of the Henrietta formation. The shaly coal blossom (No. 13) outcrops and has been mined to some extent in the south and west parts of section 20, White Breast township, at 920 to 925 feet above sea level. It is there underlain by eighteen to twenty feet of shale and overlain by two feet of sandstone. At a depth of forty-two feet below the base of the preceding surface section a good seam of coal has been mined by shaft. This deeper coal may be the same bed as the coal (bed 5 of Surface section No. 37, page 162) that is mined in Swede Hollow to the northeast at a higher elevation or it may be the Wheeler coal.

The equivalents, in part, of the upper members of Surface section No. 39 again outcrop one and one-half miles west of the preceding surface section. One-eighth mile north of the center of section 18, White Breast township, a thickness of about thirty feet of shale with a thin compact white limestone layer near the top is exposed. Above the limestone layer occurs about five feet of highly calcareous shale containing thin limestone bands and small limestone lenses. A bed of carbonaceous shale about two feet thick, lying about five feet below the limestone, is thought to represent the coal horizon (bed 13) in Surface section No. 39 given above.

These beds are believed to represent the upper members of the Henrietta formation. No other exposures are known to the west, where the Coal Measures have been deeply eroded and the Pleistocene deposits are very thick.

An exposure of Coal Measures near the center of section 9, Benton township, is believed to be equivalent to part of Surface section No. 39. It is given below.

Surface section No. 45. Southwest of middle of section 9, Benton township, along Chariton river.

		FEET
5.	Shale, gray, with limestone nodules	1
4.	Clay, yellow	1 to 1½
3.	Shale and limestone, very carbonaceous	3
2.	Shale, blue	1½
1.	Clay, yellow	1
	Base at 920 to 925 feet above sea level.	

About a quarter of a mile farther west ten to fifteen feet of yellowish clay and shale, with thin interbedded limestone layers, outcrops at an elevation slightly higher than the section given above. It is very much like the upper beds in Surface section No. 39, page 163.

The unexposed strata beneath the upper White Breast creek valleys are known from drill sections, one of which is given below.

Drill section No. 28. Old Cleveland mine, one-fourth mile west of center of section 17, White Breast township.

Curb elevation about 880 feet above sea level.

		THICKNESS		DEPTH	
		Ft.	*In.*	*Ft.*	*In.*
1.	Soil	7		7	
2.	Yellow clay	11		18	
3.	Blue clay	2		20	
4.	Blue clay, dark and gritty	11		31	
5.	Light shale	13		44	
6.	*Coal* (may be bed 28 of Columnar Section)	1	6	45	6
7.	Fire clay	2	6	48	
8.	Dark sand rock	7		55	
9.	Light shale	7		62	
10.	Dark shale	2		64	
11.	Light shale	10		74	
12.	*Coal* (may be Wheeler horizon)	2	6	76	6
13.	Fire clay	2	6	79	
14.	Gray sand rock	2		81	
15.	Dark shale with 3 inches coal and 1 foot fire clay	2	9	83	9
16.	Light sand rock with sand balls	4		87	9
17.	Light shale	10		97	9
18.	Dark shale	8	3	106	
19.	Red clay	3		109	
20.	*Coal*	1		110	
21.	Light shale	6		116	
22.	Sand rock	4		120	
23.	Light shale	12		132	
24.	Limestone	1		133	
25.	Dark fissile shale, "slate"	3		136	
26.	*Coal* (may be about horizon No. 15 of Columnar Section	1		137	
27.	Dark shale	4		141	
28.	Fire clay	4		145	

29.	Light shale	5		150	
30.	Lime rock	1		151	
31.	Blue shale	4		155	
32.	Black shale, slaty	6		161	
33.	Lime rock	1		162	
34.	Black fissile shale, "slate"	1		163	
35.	*Coal*	1		164	
36.	Dark shale	1		165	
37.	Black "slate"	1		166	
38.	Black rock	1		167	
39.	*Coal* (may be between horizons 7 and 11 of Columnar Section)	1		168	
40.	Fire clay	5		173	
41.	Gray sand rock	8		181	
42.	Light blue shale, "slate"	3		184	
43.	Black shale, "slate"	4		188	
44.	Light blue "slate"	60		248	
45.	*Coal* (Lower)	5	3	253	3
46.	Fire clay				
	Total depth 254 feet.				
	Bottom of hole 626 feet above sea level.				

The Lower coal is known to occur 622 feet above sea level at the bottom of the shaft of the old Big Hill mine at Lucas. Two higher veins also have been worked in this mine, one at a depth of 49 feet and the other at 99 feet below the curb, which is 900 feet above sea level. A somewhat generalized record of this hole is given as Drill section No. 29 in the appendix.

The Coal Measures of Otter Creek township are known only from insignificant exposures of dark shale along Otter creek, one to two miles northwest of Norwood, from the Eaton well and from the Cackler mine shaft. The record of the Eaton well is given below. From this hole it would seem that the Lower coal occurs in this part of the county, although of course, one drilling is not sufficient to establish the presence or absence of workable coal where the beds are as lenticular as they are known to be in this county. This drilling also reveals the fact that the strata below the Lower coal horizon are predominantly sandy, for the most part sandstone. It is an interesting fact that these sandy beds were dry and since the well was drilled for water it had to be abandoned. No other attempt has been made to drill for water or to prospect for coal in this township.

Drill section No. 30, "Eaton Well." Middle of southeast quarter, section 21, Otter Creek township.

Curb elevation 1000 feet above sea level.

		THICKNESS *Ft.*	DEPTH *Ft.*
1.	Soil and clay	25	25
2.	Blue "mud", drift	120	145
3.	Sand	1½	146½

4.	Coal Measures shale and *coal* seams, etc.	53½	200
5.	Purple clay shale	10	210
6.	Shale	34	244
7.	*Coal* and carbonaceous shale	4	248
8.	Shale and "slate"	18	266
9.	Hard rock (?) and thin shale at bottom	15	281
10.	*Coal,* may be in part shale (Lower coal)	6	287
11.	Sandstone and sandy shale streaks	113	400

Bottom of hole 600 feet above sea level.
Total depth 400 feet.
Top of coal (10) 719 feet above sea level.

An eighteen to twenty-eight inch bed of coal was formerly mined at an elevation of about 885 feet above sea level at the Cackler mine located in the northeast corner of section 2, Otter Creek township. Two four inch veins also were noted in this hole. The record of this shaft is given in the appendix, but no correlation of these beds is attempted, except that they are probably Upper Cherokee.

Pleasanton?—A few small exposures of Coal Measures strata occur along a small creek about one and a half miles southeast of the town of Lucas. One of these, near the northwest corner of section 30, White Breast township, shows a few feet of shale and two thin limestone beds, which, however, do not seem to be in place. No attempt has been made to correlate this exposure except that it may belong to the Pleasanton formation. Not far from the exposure noted above four feet of reddish and chocolate colored shale outcrops along the creek and is overlain by recent deposits of sand and gravel. This shale contains small concretionary nodules of red arenaceous limestone. Most of the residue of these nodules, the part which is insoluble in hydrochloric acid, is finer than silt. This shale may also be of Pleasanton age.

Chariton Conglomerate.—The Chariton conglomerate, a channel deposit of probable Pleasanton age, is well developed across a part of Pleasant township. Many of the conglomerate strata have limestone pebbles and cobbles from the Cherokee and possibly from the Henrietta limestones and the coarser beds contain abundant silicified pieces of the trunks of coal-making trees and plants. Almost all of the sandy beds are cross-bedded and reddish to buff-brown. The term "conglomerate" may be more or less of a misnomer for this formation as it is made up of far more sandstone than conglomeratic beds. However, the term Chariton conglomerate has been applied to a formation that is believed to be of the same nature and age as this one and the writer is averse to introducing new names for old ones that have priority.

The known outcrops of this formation in Lucas county extend almost in a straight line from the northwest part of section 3 to the middle of section 27, Pleasant township. South of the latter point the glacial deposits are very thick and no Pennsylvanian outcrops are known beyond this in Pleasant or Cedar townships. The width of the formation seems to be at no point over half a mile. Wherever outcrops of this channel deposit occur they lie between outcrops of Cherokee strata at the same elevation both east and west of the conglomerate sections. There is no possibility of these conglomerate and sandstone beds being of the same age as the Cherokee strata with which they lie in contact, but they are separate and distinct and much younger. It is thought that they may be equivalent to the Warrensburg and Moberly sandstones of Missouri. This point has already been discussed on pages 125 and 126 of this report. The lower limit of the formation was nowhere certainly exposed. Surface section No. 41, which follows, is quite typical of the sandy phase of this formation.

Surface section No. 41. Northwest corner section 3, Pleasant township.

		FEET
11.	Glacial drift and gravel	15
10.	Shale, sandy	6
9.	Sandstone, like 7 below	1½
8.	Sandstone, soft, brown, massive	2
7.	Sandstone, soft, and thin sandy shale partings	1½
6.	Sandstone, hard and cross-bedded	2 to 3
5.	Sandstone, sandy shale and clay, in part cross-bedded	19
4.	Sandstone, hard and quartzitic	½
3.	Shale and sandstone	8½
2.	Sandstone, soft, buff-colored	2½
1.	Shale, sandy, light colored	9
	Base at 840 feet above sea level.	

Near the center of the south side of section 3, Pleasant township, about twenty feet of brown cross-bedded sandstone outcrops. This is equivalent to the middle part of Surface section 41, given above.

Surface section No. 43, given below, is fairly typical of the more conglomeratic phase of the formation. A little less than half a mile east of this location about forty feet of Cherokee shale and coal seams outcrops at the same elevation. These Cherokee beds are correlatable with strata of Surface section No. 1, page 144.

Surface section No. 43. Along east and west road near southeast corner section 10, Pleasant township.

		FEET
11.	Loess	17
10.	Glacial drift and gravel, reddish	16 to 17
9.	Shale, sandy (covered)	2 to 3
8.	Sandstone, brown, hard, cross-bedded	3 to 4
7.	Sandstone, hard to soft, brown	2 to 3
6.	Conglomerate, hard, white to gray, siliceous	7½ to 8
5.	Sandstone, hard, brown	3
4.	Shale, sandy (covered)	3½ to 4
3.	Conglomerate, white, quartzitic	½
2.	Shale or soft sandstone (covered)	2 to 3
1.	Sandstone, red-brown, soft and cross-bedded	3
	Base at 825 to 830 feet above sea level.	

In the southeast part of section 22, Pleasant township, beds of conglomerate and cross-bedded sandstone are exposed. The conglomerate here is notable for its content of limestone pebbles and silicified wood. Near the center of section 27, Pleasant township, about 120 feet of cross-bedded sandstone with some interbedded shale outcrops in the slopes. Most of this undoubtedly belongs to the Chariton conglomerate formation.

PLEISTOCENE

The Pleistocene history of Lucas county has been outlined in connection with Topography and Drainage. The stratigraphic relations of the Pleistocene formations have been discussed under general stratigraphic relations and the thickness also has been given. It should be pointed out here that nearly all of the glacial drift exposures in the county are Kansan. The uplands are everywhere covered by a thick deposit of loess, which lies on Kansan gumbotil. This gumbotil is well exposed in nearly all of the newly made road cuts and in the railroad cuts over the county. When dry it has a gray-black color and a characteristic polygonal pattern of cracks over its surface. The overlying loess does not show this latter feature though in other respects the two formations are much alike in appearance. The gumbotil contains small quartz pebbles, which the loess does not have. When wet the gumbotil is exceedingly tough and is everything that the older term "gumbo" implies. It is quite impervious to water and on hillsides springs and seeps are common along its upper surface. Gumbotil makes a very unsatisfactory road bed for when wet it becomes almost impassable. It is necessary when building a road to either remove this stratum altogether or cover it up. In fields it retains the water in low places and cannot be worked satisfactorily when either wet or dry. It forms the poorest soil in the county.

The Kansan drift where exposed is oxidized as much as forty feet below the gumbotil. The upper five to fifteen feet of the oxidized till is usually thoroughly leached of all lime. Much of this lime is reprecipitated in small concretions in the oxidized and unleached zone. The oxidized till is usually a buff-brown or yellow to reddish, but the fresh and unoxidized till is drab to black. The "contact" of the till and the gumbotil is not a sharp line of unconformity but is a transition zone. In this zone granite bowlders may be seen in the process of disintegration and can be crushed by the hand. This transition zone is the best evidence of the origin of gumbotil, the leached product of glacial till. Unleached and unoxidized Kansan till is seen at only a few places in Lucas county. In the middle of the northwest quarter

FIG. 20.—Disintegrating granite bowlder in transition zone between till and gumbotil, near Williamson.

of section 23, English township, the unleached and unoxidized Kansan till was found to contain crushed fragments of small gastropod shells, some of which even show the shell markings.

The Nebraskan deposits are in appearance identical with the Kansan and can be differentiated with certainty only when the

Nebraskan gumbotil lies between the two tills. The Nebraskan gumbotil is on the average thinner than the Kansan gumbotil. The Nebraskan succession from gumbotil downward is the same as for the Kansan: gumbotil, oxidized and leached till, oxidized and unleached till, unoxidized and unleached till. The unleached and unoxidized phase is everywhere dark in color and contains fresh limestone pebbles.

The sections which follow are typical of the Pleistocene deposits of the county. The writer is indebted to Doctor Kay, State Geologist, for the details of these surface sections.

Corner of sections 9, 10, 15 and 16, Jackson township. Top of section is twenty feet below the loess covered upland.

		FEET
3.	Gumbotil (Kansan), dark gray to chocolate brown, some pebbles; grades into oxidized leached drift below. Top of gumbotil about 1020 feet above sea level	5
2.	Kansan drift, leached and oxidized	5
1.	Kansan drift, unleached and oxidized, dark yellow, many concretions, many quartzite pebbles and bowlders	15

An exposure about 400 yards long near the middle of section 20, Lincoln township, in the Chicago, Rock Island and Pacific railway cut is typical. Yellow Kansan till fifteen feet thick, the depth of the cut, is shown at the south end. The surface rises to the north until the cut attains a depth of forty feet. Here the following section is well developed.

		FEET
3.	Loess, yellowish to buff and brown	10
2.	Gumbotil, drab sticky clay, 1020 to 1030 feet above sea level	12½
1.	Kansan till, oxidized, upper few feet leached	18

One-fourth mile west of the village of Williamson, between sections 27 and 34, English township, the Kansan gumbotil is well shown at its maximum development. Here it reaches a thickness of eleven feet and is typical in all respects. Five feet of loess covers the gumbotil at this point but farther east it is much thicker. The gumbotil is underlain by thick oxidized Kansan till, the lower part of which is unleached and contains many concretions.

In a cut west of the railroad crossing along the road between sections 10 and 11, Lincoln township, a composite section is as follows:

		FEET
4.	Loess	5
3.	Gumbotil (Kansan)	12
2.	Till (Kansan), oxidized and leached	5
1.	Till (Kansan), oxidized and unleached to bottom of cut	5

There are some concretions in the gumbotil, the lime for which has been derived from the calcareous loess above.

The above sections are typical of the Kansan deposits. Such typical sections can be duplicated almost anywhere over the county where the upland areas have been cut into in road building.

Nebraskan exposures are rarely seen and those that follow are the best ones known in Lucas county.

A good exposure of Nebraskan till and gumbotil is shown on both sides of the road near the middle of section 25, English township. Here the gumbotil, which is approximately four feet thick, lies under forty-five feet of oxidized Kansan till and is underlain by oxidized Nebraskan till. The elevation of this gumbotil is 960 to 970 feet above sea level.

The Nebraskan gumbotil is fairly well developed near the north middle of section 11, Union township. At this place it is about 1040 feet above sea level and its relation to the upland and to Kansan till, a few rods farther north, offers quite conclusive evidence that it is Nebraskan gumbotil. There are other similar exposures along the main road one-half to three-quarters of a mile farther south.

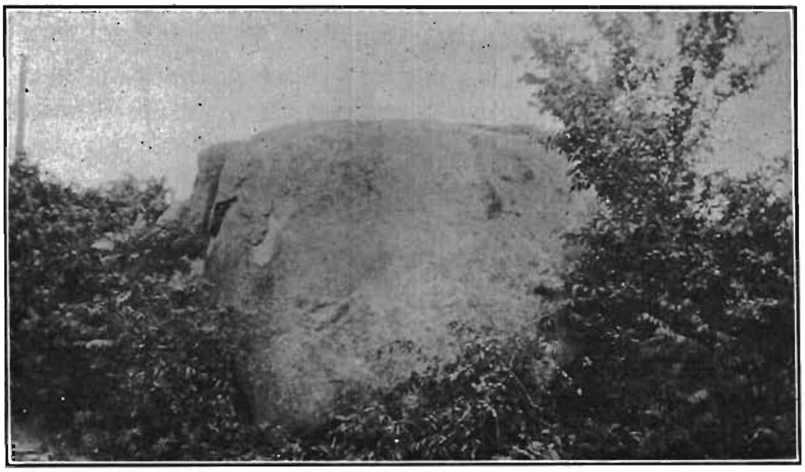


FIG. 21.—Large Kansan bowlder northwest of Norwood.

In the northwest corner of section 24, Benton township, four feet of Nebraskan gumbotil is exposed. This is a typical exposure with Nebraskan till below the gumbotil and Kansan till above it. The elevation of the gumbotil is 960 to 965 feet above sea level.

The relations of the Pleistocene deposits to the Coal Measures and the thickness of the glacial formations have been discussed already on pages 134 to 139 inclusive. The data are summarized in the table on page 135 and shown graphically on Plate I, page 136.

Dr. G. F. Kay, State Geologist, has listed and described a number of large Kansan bowlders from Lucas county.[24] Some of these are included in the following list.

Kansan Bowlders from Lucas County.

LOCATION	SIZE *Feet*
NW. ¼ of SW. ¼, sec. 32, White Breast township	8 by 7 by 6
West side of road between sec. 31, Benton township, and sec. 36, Warren township	10 by 9 by 6
NW. ¼ of sec. 15, Otter Creek township	25 by 20 by 16
SE. ¼ of sec. 13, Liberty township	12 by 9 by 7
NW. ¼ of sec. 36, Jackson township	9 by 6 by 3
Middle of sec. 17, Pleasant township	23 by 15 by 10
NW. part of sec. 5, Liberty township	5 by 5 by 2

All of the above bowlders are of granite. Other smaller bowlders are known in a number of places.

Economic Geology

COAL

HISTORY OF COAL MINING IN LUCAS COUNTY.

"Lucas county formerly contained the largest and deepest mines in the state. It was in this county that the first and almost only successful experiments in regard to the nature and capabilities of Iowa coal were carried on extensively. These investigations were made by the White Breast Fuel Company, which operated largely in this county. The experiments were made with special reference to the determination of the adaptabilities of the various varieties of coal; their coking properties and the utilization of slack and coal dust. In regard to the latter, briquettes were manufactured in various ways, but it was found that with the methods used the coal dust could not be economically compressed and cemented for commercial pur-

24 Iowa Geol. Survey, vol. XXVII, pp. 347-353.

poses."[25] The most practical use for which Lucas county coals have been found suitable is for boiler firing; as "steam coals" they are quite highly esteemed.

The first discovery of coal in Lucas county is accredited to a ground hog burrowing in the banks of North Cedar creek in the vicinity of or east of the Briggs drift mine. To whom or the exact date when this fact became known the writer has been unable to learn, but it was considerably prior to St. John's visit to the county in 1867. In 1860 the county produced 945 tons of coal. In the summer of 1867 when St. John made a survey of this area he recorded drift mining along North Cedar creek and its branches in the northeast part of Pleasant township and at Dale's mine near the center of Pleasant township, along English, Little White Breast and White Breast creeks. One of his type exposures, as has been previously stated, was at Wheeler's mill (near Wheeler's bridge); an upper "Wheeler" coal and a lower "Panora" coal were being mined there at that time. All these mines were small and of very local importance. No attempt has been made to record the history of all of the drift mines of the county or to locate them on the map. The duration of any one of these has been so short and their production and aggregate importance have been so small that such a record would be of little value. However, the localities where beds or seams have been worked are mentioned in the preceding section on the detailed and local stratigraphy.

In 1868 the production was 37,283 bushels or 1491 tons, but the beginning of coal mining history in Lucas county dates from 1874, when in June Mr. William Haven and others leased 540 acres of land on White Breast creek about two miles east of the town of Lucas. The leased lands belonged wholly or in part to Col. Byron O. Carr of Galesburg, Illinois. About a year later the White Breast Fuel Company was organized and Mr. Haven became associated with Wesley Jones, J. C. Osgood, Louis R. Fix of Burlington and J. T. Potter. Mr. Osgood was made president of the company.

In the first prospecting of the White Breast field a number of holes were drilled. After many delays and much trouble, due mostly to financial difficulties, on January 16, 1878, five feet, four

25 Lees, James H., History of Coal Mining in Iowa: Iowa Geol. Survey, vol. XIX, p. 550.

inches of coal was reached. This marks the beginning of development in the White Breast field, one of the most productive in its day. James H. Lees, in his History of Coal Mining in Iowa,[26] states "..., a field from which a greater tonnage has been raised in shorter time than from any other field in the state." This interesting beginning is best told by a further quotation from Lees' paper: "The shaft was 250 feet deep and an eighty horse power engine was used for hoisting the coal. Tail-rope haulage was installed in 1882. Electricity was used for lighting the mine, the first installation in the state. When the Mine Inspector made his first report in 1880, 405 men and 52 mules were employed and were raising 640 tons per day. The quality of the coal was considered superior to that of any other then produced in the state and the coal acquired a great reputation and an extensive market. White Breast No. 1 was the first mine to adopt the plan of shot firing once a day. This avoided the danger of explosions when the men were in the mine and also kept the air pure for the men and mules." This company operated several mines in this field and in 1880 the production was 126,490 tons, making the county an important Iowa producer.

About 125 diamond drill holes were put down north and east of the White Breast Company mines in the years 1884 and 1885 but did not find any additional workable coal. Conditions in parts of the field being worked were so unfavorable that by 1891 the field was considered worked out and the large mines of the White Breast Company were abandoned. Production had risen to 594,450 tons in 1886; it dropped to 339,229 tons in 1890 and then in 1891 fell off to practically nothing. Lucas county did not again become a producer until Mr. Haven resumed operations in 1899.

There were some other more or less abortive attempts to work the Lower coal but none was notably successful. In 1877 or 1878 Daniel Eikenberry of Chariton sank a shaft a mile and a half east of White Breast No. 1. This penetrated sixty or seventy feet deeper than the White Breast mine but did not find conditions favorable and hence was not developed. In 1879 a coöperative company of miners and business men of Chariton was organized. The more prominent of these men were S. H. Mallory,

26 Lees, James H., Op. Cit.

D. Q. Story and D. M. Thompson and the company was known as the Chariton Co-operative Coal Company. This company sank a shaft to a depth of 330 feet, the greatest depth of any mine in Iowa at that time. It was located about three-fourths mile north of the Eikenberry shaft. The coöperative scheme did not work well and soon a reorganization was effected, the business men taking over complete control. They, not being experts in mining, did not succeed, for as a consequence of unwise mining methods disastrous slumping and caving resulted and the venture had to be abandoned. They also had a good deal of trouble with water. The equipment was up to date and adequate.

In 1877 the Union Coal and Mining Company of Ottumwa under the direction of its president, J. C. Peasley of Burlington, sought to enter the White Breast field. This company acquired the shallow Ladow shaft, which it deepened to the Lower coal, here five feet in thickness and at a depth of 300 feet. After considerable expenditure of money and the opening of several entries, the company abandoned the mine on account of the troublesome and excessive quantity of water, which it was inadequately equipped to handle. In 1899 this mine passed into the possession of Hon. H. L. Byers, associated with George Ramsey of Oskaloosa and Messrs. Shuler and Bates of Illinois. They reconditioned the old shaft and using it as an air shaft sank a new main shaft to the west of it. The water was pumped out and the mine operated for about a year when it passed into the hands of S. W. White of What Cheer and of White City, and others. About a year later it was transferred to Mr. Reed of Illinois and he, with Mr. Byers, operated it for two months and then Mr. Moody of Kansas became part owner. Work was again discontinued late in 1907.

About 1878 the Farmers Co-operative Coal Company was organized and opened a mine at Zero on the Chicago, Burlington and Quincy Railroad a mile and a half west of the Monroe county line. The shaft was 260 feet deep and reached the Lower coal, which is five feet thick at this place. This mine passed through several changes in ownership and was last operated under lease by the White Breast Fuel Company. After being worked more or less continuously for less than ten years it was finally abandoned owing to the large amount of poor coal and the "bowlders" in the coal and also on account of water entering through the sandstone roof. Where Lucas county mines, such as this and some in the White Breast field, had a sandstone roof water has usually been one of the main causes of abandonment, but on the other hand a shale or "slate" roof usually means a dry mine.

In 1890 the county's production was 339,229 tons; in 1891 it dropped to almost nothing. Between 1891 and 1899 Lucas county was almost a nonproducer, except for the local drift mines working upper thin veins.

Mr. Haven, previously referred to, had sold his interests in the White Breast mines to Mr. Osgood in 1883 and also bound himself not to engage in mining along the Burlington line for ten years. He with others reorganized the White Breast Fuel Company in 1896 and began extensive prospecting along Little White Breast creek northeast of Chariton and also in an area southwest of Lucas. In this latter field fifty diamond drill holes were bored, which resulted in the opening of the Cleveland mine No. 4, at New Cleveland, two and a half miles southwest of Lucas, in 1899. The shaft was sunk to a depth of 326 feet to coal 4.9 feet thick. The new mine was well equipped with motor haulage and steel tipple and had a capacity of 1000 tons a day.

The prospecting of Mr. Haven along Little White Breast creek resulted in the discovery of a rich field of 1200 to 1600 acres of good coal about three and one-half miles northeast of Chariton. The Inland Fuel Company was organized and in the summer of 1901 the sinking of the Inland mine No. 1 shaft was begun. This marks the beginning of development in the northeast quarter of Lucas county. Had this area been served by a railroad development would have been rapid, but as this was not the case expansion did not take place for some years. Work in the new mine, No. 1, was limited more or less to driving entries and preparing it for large production. The coal had a shale roof and the mine was practically dry. By 1907 it was so developed and equipped that on short notice it could have been made to produce a thousand tons daily. It had no shipping facilities and was only a wagon mine, but the coal was good and was in great demand. The persons interested in the Inland mine pushed prospecting for a number of years and succeeded in locating a number of basins in the northeast quarter of the county aggregating more than 10,000 acres of coal ranging from five to eight feet in thickness. Development was delayed a number of years pending ownership settlements and the coming of transportation facilities.

In 1899 the county's production was 32,419 tons and in 1900 it amounted to 227,921 tons. Production started to decline again about 1904 and in 1908, when Cleveland mine No. 4 was abandoned, it had dropped to 74,288 tons. The Big Hill mine at Lucas had closed in 1907.

In 1908 Lucas county did not have a single mine doing a shipping business and the only mine working the lower vein was the Inland No. 1 above referred to, northeast of Chariton. The mine inspectors' report for 1908 mentions a local mine operating an upper vein by the long wall method. This was located northeast of the town of Lucas and was owned by the Skidmore Brothers. No new mines were reported and the same two referred to above were operating for local trade during the next two years. The production in 1909 from the two local mines was only 9,717 tons and only 41 men were employed; in 1910 the same mines produced 10,410 tons and employed 38 men. The same state of affairs continued through 1911, when the production was 10,895 tons and 24 men were employed, and in 1912, when the production amounted to only 15,457 tons and 40 men were employed. The mine inspectors' report in 1912 showed that the Skidmore mine had been closed but the Goben Coal Company was operating in the same vicinity. In 1914 both the Skidmore Brothers and the Goben Coal Company were operating shallow shaft mines and were mining by the room and pillar method.

In 1913 a branch of the Chicago, Rock Island and Pacific Railway was built from Des Moines to Allerton, passing through the new coal field in the northeast part of Lucas county. This gave the Inland Fuel Company's mine No. 1 the long waited-for railroad connection; it was then that Lucas county started on its present career of productiveness. The Inland Company at about the same time changed hands and the new company, known as the Central Iowa Fuel Company, with Mr. Josh Norwood as general manager, was organized, with headquarters in Des Moines. The old wooden headgear of mine No. 1 was immediately replaced by new up-to-date steel equipment, including tipple, scales, shaking screen, etc. New boilers and new first motion engines were installed also and production was increased from an almost insignificant amount to about 1200 tons per day of mine run coal. Better facilities for underground handling also were added. In 1915 gasoline motors were tried for underground haulage in mine No. 1 and proved a positive failure. Tail rope haulage was later installed with entire success.

Another mine was opened in the spring of 1914 by the Central Iowa Fuel Company in a new basin in Pleasant township, about fifteen miles northeast of Chariton. This was known as mine No. 2 and is still an important producer. The coal in No. 2 was found to be seven feet ten inches thick at the bottom of the shaft and the basin contained about 6000 acres of good coal. The entire basin has not been worked from one shaft but, as will be seen below, mine No. 3 also was sunk into this basin. The same coal will be worked also from a new shaft not yet definitely located.

In 1913 Lucas county produced 13,258 tons of coal from three mines and employed 37 men. During the last half of the calendar year 1914 the production was 175,328 tons. By the end of the calendar year 1915 Lucas county ranked fifth among the coal producing counties of Iowa, with mines No. 1 and No. 2 as the only producers except the two local mines near Lucas. The production for the calendar year 1915 was 428,682 tons. In 1916 mine No. 3, also in Pleasant township and in the same basin as mine No. 2, was opened by the same company. It was developed to a capacity of 700 tons daily. The county's production in 1916 was 619,455 tons and in 1917 it was 610,230 tons.

Production fell off somewhat in 1918 and 1919 and increased again in 1920 and 1921. The Central Iowa Fuel Company opened mine No. 4 northeast of Williamson in 1920. This mine has a capacity of 2000 tons daily and is one of Iowa's finest mines.

The Iowa-Nebraska Company opened a mine southwest of Lucas in 1919 and equipped it with steel tipple and the most up-to-date machinery. It had railroad connection with the Chicago, Burlington and Quincy Railroad. This mine operated more or less continuously with rather indifferent success due to unfavorable natural conditions and financial difficulties until the early part of 1923; in the summer of 1924 the equipment was dismantled and sold at auction. This has been the only serious attempt in recent years to reënter the old White Breast field. It was not a large producer.

The local mines at Lucas, the Goben Coal Company and the Skidmore Coal Company, continued operation until 1919. In 1922 or 1923 Mr. Evan Daniels reopened the old Big Hill mine at Lucas and has been working one of the upper veins by the long wall method. Mr. Daniels' operations are not on a large scale; he supplies only local trade and works intermittently.

During the summer of 1924 the Central Iowa Fuel Company was the only important producer, operating mines No. 2, No. 3 and No. 4 in this county and No. 5 at Melcher in Marion county. Its mine No. 1 was abandoned in 1922 after mining out about 500 acres of coal. Mine No. 3 is nearing the end of its productiveness and may now have been abandoned. The above company was planning also to open a new large capacity mine in the same field in which No. 2 and No. 3 are being operated. There is a slight temporary decrease in production due to the decrease in output of mine No. 3.

The Central Iowa Fuel Company during the summer of 1924 had its headquarters in Des Moines with Mr. E. A. Hollingsworth as president and general manager. Mr. W. M. Malone, assistant general manager, is in charge of operations, with offices in Chariton. Mr. C. O. Anderson is general superintendent, Mr. F. W. Trost mining engineer and Mr. H. L. Jackson consulting engineer. The organization has been especially successful in planning and maintaining operations so as to avoid slumps in production due to unbalanced development in the mines. It has maintained a steady production with very little loss of time or efficiency and has constantly looked after the safety and welfare of its operatives.

In 1924 only four drift mines were in operation in the northeastern part of Pleasant township; they supplied a very local trade and employed only seven men. The Cackler mine northeast of Norwood had operated in a shallow vein for a short time and supplied a good local trade but due to various difficulties, not inherent in the mine or conditions of operation, the mine was closed.

Apparently only a small per cent of the total mineable coal in the northeast quarter of Lucas county has been removed. Probably as much as 80 per cent of the original good workable coal in this general field still remains in the ground. In-as-much as some other parts of the county, as Otter Creek township and parts of Liberty township, Union, Warren, parts of Benton and Washington townships have not been thoroughly prospected there is the possibility of the discovery of new coal basins. The probability is that Lucas county will continue to be an important coal producing county for at least twenty years and possibly for thirty years at the present rate of production.

STATISTICS OF COAL PRODUCTION FOR LUCAS COUNTY.

The following tables give as complete a summary of the coal production for Lucas county as it seems possible to get. The data for years prior to 1904 have been taken from the Iowa Geological Survey reports, principally Vol. XIX, and the data including the years 1904 and up to date, have been taken from the Biennial Reports of the State Mine Inspectors. The data for the period from 1904 to date are considered as reliable as can be gotten. The two supplementary tables for the years 1920 to 1923 inclusive give the output of the mines in greater detail and also the distribution for those years.

It should be borne in mind that prior to 1915 the statistical year of the Mine Inspectors ended on June 30. The last half of the calendar year 1914 is therefore given separately. Beginning with the calendar year 1915 the statistical year ends on December 31.

Statistics of Coal Production

Year	Tonnage	Year	Tonnage	Shipping Mines	Local Mines	Total Number of Employees
1860	945	1903	295,554			
1868	(37,284 bushels)	1904	239,384			
1880	126,498	1905	165,256			
1883	546,360	1906	151,432			
1884	460,017	1907	126,579	2	2	237
1885	492,750	1908	74,288	1	2	170
1886	594,450	1909	9,717	—	2	41
1887	529,758	1910	10,410	—	2	38
1888	408,765	1911	10,895	—	1	24
1889	339,229	1912	15,457	—	2	40
1890	*351,600	1913	13,258	1	2	37
1891	*800	1914	140,758	2	2	363
1892	*1,000	1914**	175,328	2	2	512
1893	*482	1915	428,682	2	2	786
1894	*1,127	1916	619,455	3	1	848
1895	———	1917	610,280	3	1	807
1896	———	1918	499,543	3	2	710
1897	———	1919	398,859	4	2	680
1898	6,600	1920	520,371	5	?	680
1899	32,419	1921	539,225	5	?	859
1900	227,921	1922	439,107	4	1	1,020
1901	221,058	1923	704,321	4	1	906
1902	246,400	1924	640,772	3	1	726

*Combined with Jefferson county ** Last half of Calendar Year

Output of Mines in Tons

Year	Lump	Run of Mine	Slack	Total
1920	86,757	334,340	99,274	520,371
1921	52,085	447,072	40,068	539,225
1922	41,763	371,624	25,720	439,107
1923	86,229	578,642	39,450	704,321
1924				640,772

Distribution of Coal in Tons

Year	Sold to Local Trade	Shipped to Points within The State	Shipped to Points outside The State	Sold to Railroads	Used at Mines	Total
1920	5,600	37,371	12,944	449,284	16,174	521,373
1921	3,440	37,268	9,425	471,949	17,143	539,225
1922	5,276	33,902	3,351	375,265	13,310	439,107
1923	3,347	37,276	425	643,452	19,821	704,321
1924	2,538		618.073		20,161	640,772

SITUATION AND NATURE OF THE COAL

The coal beds are divisible into "lower" and "upper" horizons. The "lower" horizons, particularly the horizon designated by miners and operators in the county as the Lower coal, are the more important. The Lower coal has yielded the greater bulk of the coal so far mined. The lower coal beds are characteristically lenticular, locally thick and of only limited extent. The areal extent of these "basins" of workable coal is usually measurable in hundreds of acres, in most cases less than a thousand acres. The "upper" horizons are more persistent, more traceable and admit of correlation over wider areas. The best example of such a coal bed is the one exposed in the bed of White Breast creek at "Wheeler's" bridge in section 33, Liberty township, and also identifiable at many other widely separated places over the northern part of the county. This coal bed, designated White Breast coal, is found in sections where the sequence of coal, limestone and shale beds is nearly everywhere the same, showing that these strata are as widespread in their distribution as the coal. The upper horizons belong to the upper part of the Cherokee and to the Henrietta formations. The lower more lenticular horizons are entirely in the Cherokee formation. A coal which is workable at one point may so thin out and change in quality that a few hundred feet away it is only a carbonaceous film or a thin black shale. Some of the thinnest and most inconspicuous "coal blossoms" exposed on the slopes have been traced within only a few rods distance to workable coal as much as two feet in thickness.

This inconstant and lenticular character of the Lower coal in particular, has necessitated a large outlay of capital in prospecting the fields where it is worked. In prospecting a basin and in determining the location for a new shaft a hole is drilled on at least every forty acres and in some cases, in parts of a field, on every ten acres. A prospect hole on every ten acres is expensive and sometimes unnecessary, but it usually pays to "drill a basin" thoroughly. Most of the prospecting in recent years has been done with a small churn drill, although diamond drilling was extensively employed in the past. The effectiveness of the churn

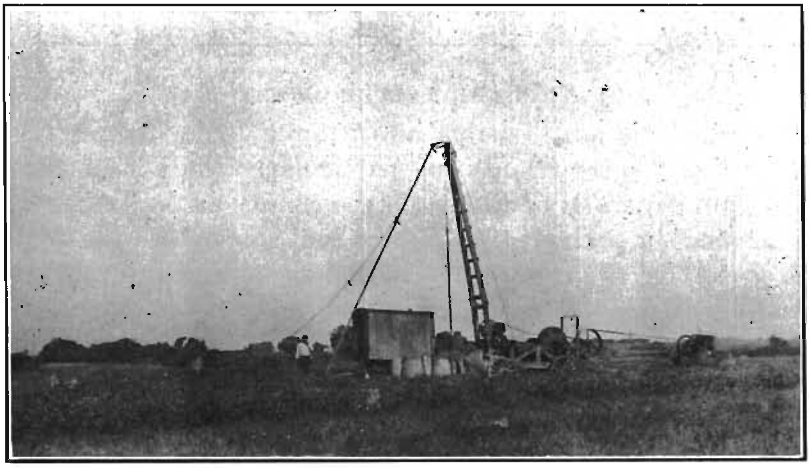


FIG. 22.—Prospecting drill rig.

drill is proportional to the skill of the driller. Where there has been extensive diamond drilling, as there has been in Lucas county, these old records serve for reference while for detailed local prospecting the churn drill is satisfactory and very much less expensive.

In locating a new shaft on one of these irregular lenticular basins many factors must be considered. Ideally a shaft should penetrate to the deepest part of the thickest coal as near the middle of the basin as possible, to facilitate underground haulage. In Lucas county this may necessitate a deep shaft sunk from the upland whereas a shaft sunk in a valley might reach the same coal a few hundred yards distant at half the depth but near the edge of the basin. It is usually easier to build a railroad track in a valley than to build a spur to a mine on an isolated upland area and the surface operating cost may also be much less in the former case. In the case of mine No. 3 it was more economical to locate the shaft in a valley near the edge of the basin, in this case nearly 2000 feet from the best coal; the hoisting distance is less than two-thirds what it would have been from the upland. Railroad spur building was facilitated in this instance and tail rope underground haulage proved economical. In mine No. 4 the shaft is ideally located with respect to the coal, and surface transportation is easy along the continuous upland divide. The hoisting distance is nearly 300 feet.

The coal beds in addition to being lenticular are also undulating. This variation from horizontality commonly is as much as forty feet and is known to be as great as sixty feet within a single basin. The coal is in few instances level for any distance, a condition which necessitates a large amount of work being done by the company in shooting down top, or shooting up bottom as the case may be, in order to maintain roadways at practical grades.

The explanation for this undulatory nature of the coal beds involves several factors. In general the thicker and better coal is at the lowest points. These places were originally the deeper places of accumulation in the "swamps". The thinner coal was formed in shallower parts of the basins on higher bottom. The undulations are then in part due to irregularities of the surfaces of deposition and are thus in part primary. Another factor is unequal settling of the Coal Measures sediments, the greater settling taking place where the newer deposits were thickest. It is believed that this is the primary cause of minor structures in the Coal Measures and is in part the cause of the undulating nature of the coal beds. It is quite certain that the "rolls and pitches" so characteristic of the Coal Measures are structures developed while the sediments were soft and are due to unequal settling. Small faults are similarly accounted for.

The shallower coal beds and the veins exposed at the surface show the same undulating character. They are thinner as the basins were shallower and the surfaces of deposition more even. The magnitude of the undulations is much less than it is for the deeper coals. It is seldom greater than fifteen to twenty feet in the upper beds.

The attitude of the strata and particularly of the coal beds is largely accounted for above. In addition these beds have been subject to all diastrophic deformation affecting this area since their deposition. This does not seem to have been locally important and diastrophism has been responsible only for the general monoclinal dip to the southwest.

Good coal may be "cut out" in places by channel or stream erosion during Pennsylvanian time or during subsequent time preceding glaciation. Exact knowledge of such "cut outs" is important where the workable basins are as small as they are in Lucas county. This also necessitates extensive drill prospecting. Faulting is practically unknown in Lucas county, so does not enter as a factor in the miners' difficulties. One true fault of very small throw was known in mine No. 1, now worked out and abandoned. Henry Hinds in "The Coal Deposits of Iowa",[27] discusses and illustrates the characteristics and peculiarities of the occurrence of Iowa coal.

PRINCIPAL KNOWN BASINS AND PRESENT HOLDINGS

Probably as many as eight or nine basins of Lower coal are known in Lucas county. Some have been worked out and are now abandoned; others have not been opened up and at least two and possibly three basins are now being worked by the Central Iowa Fuel Company.

The former White Breast Company operated in a field of probably two basins. These basins were connected by a stratum of thin coal and carbonaceous shale. The White Breast mines east of the town of Lucas, the Old Cleveland mine, and the Big Hill mine in Lucas operated in one basin. White Breast No. 4 at New Cleveland operated in the other basin. The Iowa-Nebraska mine worked the same coal as the New Cleveland mine had worked, but at a later time.

The coöperative mine at Zero, now abandoned, operated in a distinct basin, lying only in part in Lucas county.

The Central Iowa Fuel Company's mine No. 1, now abandoned, worked out a pocket or basin located about three miles northeast of Chariton. This coal lens may be more or less connected with the basins in which the same company's mines No. 2, No. 3 and No. 4 are now operating. The pockets of coal being worked by mines No. 2 and No. 3 may lie in a single basin but are more likely separate in the same manner as the White Breast basins. Mine No. 4 is operating a distinct basin but at the same

27 Iowa Geol. Survey, vol. XIX, Ch. I, pp. 25-32.

horizon as the coal in mine No. 2. A new shaft is to be put down northwest of mine No. 2 and in the same pocket.

The "Holmes" field, southeast of Williamson, has been prospected but has not been opened up. It is thought to contain about a thousand acres of workable coal. Other basins in the northeastern part of the county are fairly well known.

The Lower coal is believed to have been penetrated in the Eaton well in Otter Creek township at an elevation of 719 feet above sea level. No prospecting has been done but a workable basin of coal may exist in this township.

Prospecting in Benton township has been very unpromising and little is known of the coal possibilities in Union, Warren or Washington townships.

Little attention has been given to the shallower and thinner coal beds; none has been worked on a large scale. Some of these thinner beds have good roofs and are thick enough to work but will likely not be developed on a large scale as long as Lower coal bodies are available. So far it has seemed practicable to work but one level in a mine and in nearly every case that has been the Lower coal. This coal is believed to belong to a single horizon, although as has been shown above it lies in several basins which are more or less separate and in some cases entirely unconnected. It is believed that these basins represent coal formation during one interval of time but in more or less separate "swamps".

In 1924 the Central Iowa Fuel Company held the coal rights on about 7500 acres. The Victor Fuel Company (C.F. Osgood) held 600 acres in the basin formerly worked by Central Iowa Fuel Company's mine No. 1, but had no development under way. The Maple Block Coal Company held 600 acres of coal land in Pleasant township. The Consolidation Coal Company has a field on Whites creek in Monroe county and development of this field will likely lead to an increase in acreage, possibly into Lucas county. The Consolidated Indiana Company holds 200 acres of coal land in the northern part of this county, an extension of its Melcher field in Marion county.

MINING METHODS

All the coal mining in this county is done by the room and pillar method. The double entry system is employed in all the mines. The two entries are driven parallel and twenty to thirty feet apart. They are connected every sixty to seventy-five feet by break-throughs or connecting passages. The entries are six to eight feet wide with ample head clearance and are laid out according to a rectangular or panel plan. Rooms are driven off from these entries at distances from thirty to fifty feet, with an average distance between centers of thirty-five feet. These rooms from which the coal is removed are rectangular and average about twenty-five feet in width. They are driven to depths ranging from one hundred to two hundred feet, usually averaging about 160 feet. Room entries are so spaced that rooms worked from opposite sides of a panel break together. The pillars between rooms are relatively narrow, in some cases being as narrow as six feet, and very little pillar robbing is done.

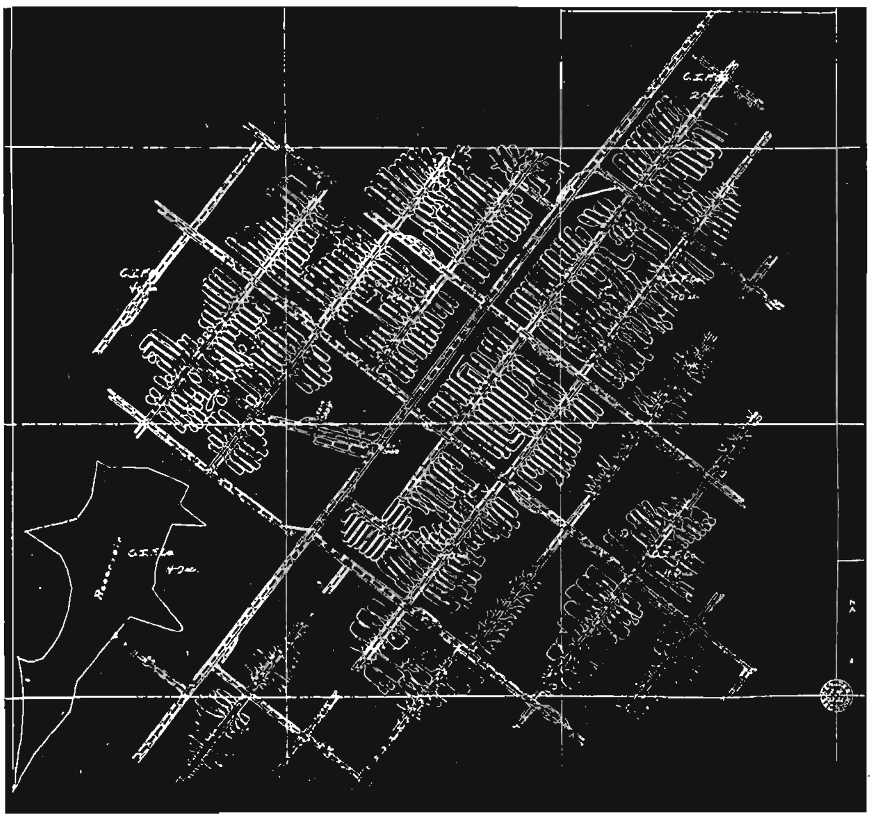


FIG. 23.—Map of underground workings of mine No. 4, Central Iowa Fuel Company.

The rooms are driven narrow for six to ten feet from the entries and thence widened rather abruptly to their full width. The neck or room doorway averages about eight feet in width. "Break-throughs" are made through the pillars at frequent intervals, connecting adjacent rooms. This facilitates the circulation of fresh air near the working face.

The thickness of the Lower coal averages about six feet; in some places it is as much as eight feet and it is seldom worked where it is less than four feet. The thickness of the coal allows ample head room in all rooms and entries without the removal of much top or bottom.

The coal is either undercut by machines and shot down or is "shot off the solid." Shot firing is done at one time and only once a day, at 4 p.m. The coal thus shot down is broken and loaded by the miners the next day. In addition the miners undercut the working face and place the shots for the next firing. In this way a day's output for a room is determined by the amount shot down the day before. Each room is worked coöperatively by two miners. They must maintain their tracks from the entry as close to the working face as possible and do

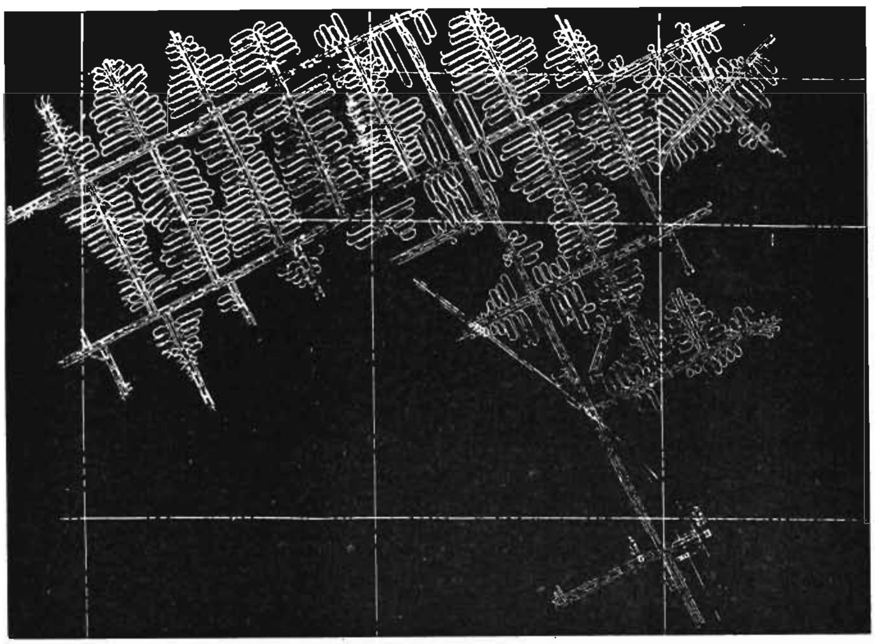


FIG. 24.—Map of underground workings of mine No. 3, Central Iowa Fuel Company.

their own timbering. The necessary props are delivered to the rooms on requisition. The timbers are placed quite regularly and are long enough to extend from the floor very nearly to the roof, where they are wedged by a cap piece.

Partings or switches are conveniently placed. Entry timbering and roadway maintainance are done by separate crews of men employed for that work. Timber supplies are kept underground near the main shafts where distribution is easy.

Ventilation is accomplished by steam or electrically driven steel fans that force fresh air down the air shafts. The proper distribution of air through the underground workings is brought about by the use of doors, curtains, brattices, stoppings, overcasts and undercasts. The Lucas county mines are free from obnoxious and poisonous gases. As firing is done only once a day, when few men are in the mine, any gases resulting from firing are easily swept out before the next working shift goes in.

Mines now working the Lower coal are essentially "dry". The thick impervious roof shales, "slates", effectively hold out the ground water from above. This was not the case in some of the early mines operated by the White Breast Company. For the most part the passage ways of the Central Iowa Fuel Company's mines are dry even to dustiness. The little water that collects in the sump, at the bottom of the air shaft, is used to sprinkle the roadways. All of the mines are equipped with pumps and collecting cisterns or sumps so as to be able to handle any amount of water likely to be encountered. So far all of the mines in the northeastern part of the county have been entirely free from water trouble.

Underground haulage is effected by mules and mechanical power. The gathering from the rooms is done by mules and the trains of loaded cars are hauled to the main shaft by electric locomotives or by tail-rope, or in part by each. The distribution of empties is accomplished by the reverse of the above scheme. Goodman electric locomotives are used. Power for the tail-rope system is in every case supplied by a first motion steam engine at the surface. The tail-rope system has proved very efficient in every case and speeds of twenty to thirty miles per hour are attained with loaded trains of twenty-four cars. The tail-rope system is especially well adapted to long hauls in one direction.

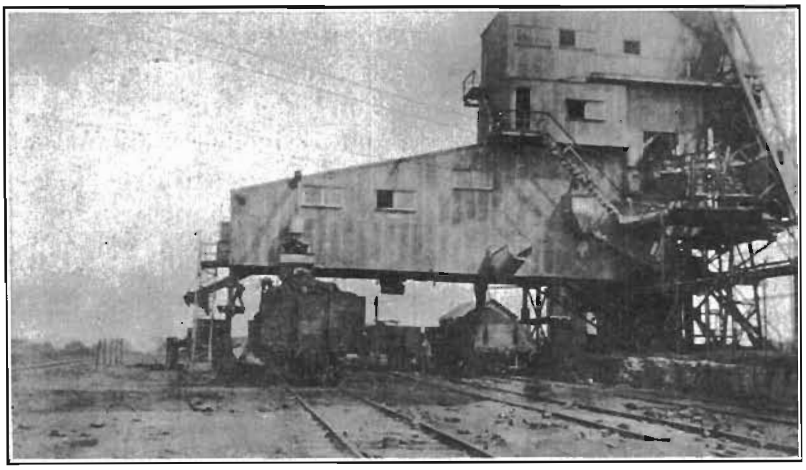


FIG. 25.—Loading tracks at Central Iowa Fuel Company mine No. 4.

The electric locomotive is better adapted to shorter hauls from several directions. This is the case in mine No. 4 where the tail-rope is not used. The prime essentials to efficient underground haulage are good road beds and carefully maintained tracks. The road beds in these mines are excellent and the tracks are good.

Hoisting is done by a system of "balanced cages". The steam engines are direct motion and operate a single drum and each cage is connected to this drum by a separate rope. The two

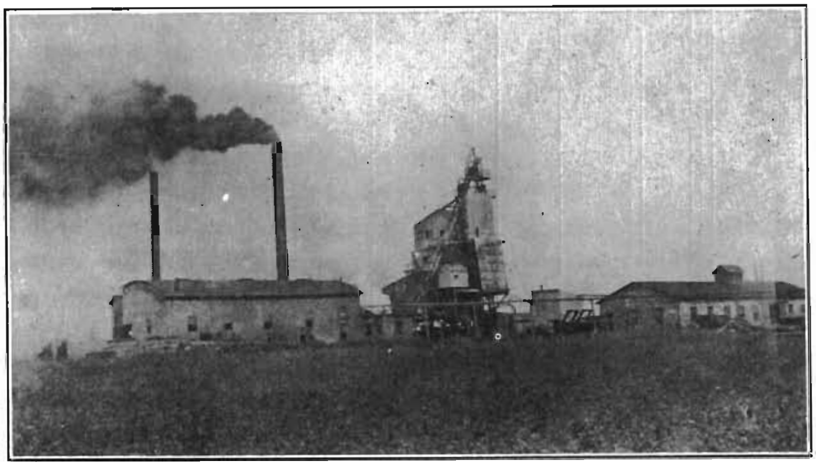


FIG. 26.—General view of power house, tipple and machine shop of Central Iowa Fuel Company mine No. 4.

cages moving simultaneously are balanced through the drum but are not attached to the two ends of a single rope. As one cage is lowered its rope unwinds from the drum and at the same time the rope of the rising cage winds onto the drum. This system of having each rope rigidly attached to the drum eliminates the possibility of slipping and the greater danger of dropping both cages in case of a break, as might happen with a single rope. It also simplifies the matter of indicator adjustment. Signals for hoisting are given to the engineer only from the bottom, except when the top man wishes to lower timber, etc.

FIG. 27.—Tipple of mine No. 4.

The shafts are wood lagged with a heavy collar of concrete. Except at mine No. 3 the tipples are of steel and up to date in every respect. As many as three tracks are laid under the screen house to receive the separate grades of coal. A small screen takes out fines for boiler fuel, which is taken to the boiler house on an elevated tramway. The auxiliary power units are either steam or electric. The tendency is to electrify all auxiliary power units in the present mines. It is probable that future mines will be completely electrified, having one central generating unit and the hoisting also will be done by electric power.

MINES IN OPERATION, 1924

Central Iowa Fuel Company, Mine No. 4.—Number 4 is the largest and most important producing mine in the county. It is located near the middle of the west half of the northwest quarter of section 24, English township, northeast of the village of Williamson, on the upland. Its topographic position facilitated railroad building and also the level ground makes surface handling of railroad cars easy. It was opened in 1920.

The detailed record of the strata in this shaft has been given in Drill section No. 35, page 153. The curb elevation is 1004 feet above sea level and the Lower coal was reached at a depth of 286 feet or 718 feet above sea level. At this point it was found to be six feet, nine inches in thickness. The thickness of the coal averages about six feet. It is overlain by a few inches of "shoddy" top and by nearly fifty feet of roof shale that is alternately red and dark banded. The bottom is a dark bluish clay grading downward into "fire clay". The total depth of the shaft is about 310 feet.

Five Goodman shortwall mining machines are used for undercutting the coal. There is also good shooting coal and some is "shot off the solid". Gathering is done entirely by mules, of which seventeen are in actual use and are stabled underground. Haulage is done by three Goodman electric locomotives, which handle trains of twenty-four cars, each car carrying an average load of 3600 pounds. The cars are handled at the shaft bottom by automatic cagers and are hoisted on self-dumping cages from which the coal is delivered to the weigh pans and then goes to the sizing screens or to the mine-run chute. Several grades of coal can be delivered to the cars under the screen house as follows: Lump, "Fancy Chunk", "Egg", "Fancy Steam", Mine-

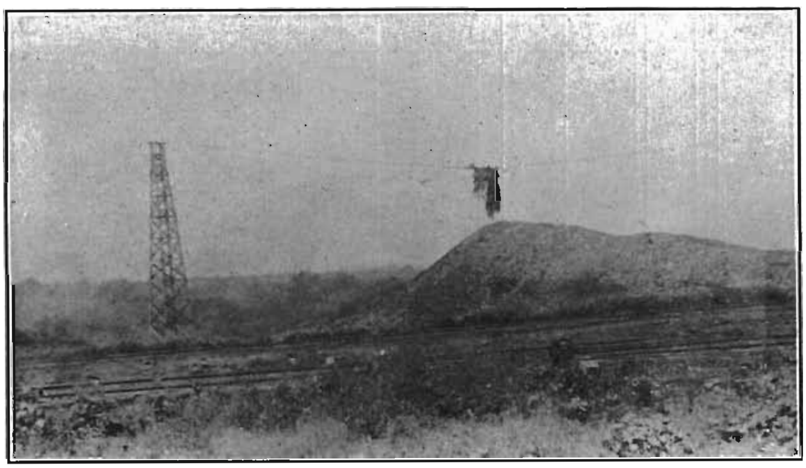


FIG. 28.—Rock dump, Central Iowa Fuel Company mine No. 4.

run and Slack. An underground timber yard is maintained near the main shaft.

The rock waste is hoisted only on the south cage and is dumped into the rock hopper from which it goes to an aerial cableway bucket. The bucket is carried by an 800 foot cable way reaching to a tower, as shown in figure 28. At any desired point along the cable a trip is placed and this automatically dumps the loaded bucket. A ridgelike dump is thus built up, reaching from any desired distance from the tipple to the tower. When the pile reaches to the tower and to the maximum height the tower is moved; the pile is thus spread out fan-shaped over a large area.

The tipple is entirely of steel and is modern in every detail. The power house is equipped with five 150 Horse Power boilers. The hoisting engine is in the tipple end of the building. To the right of the hoisting engine is a 275 K. W. D. C. engine-generator unit. There is also a 30 K. W. auxiliary unit. An adequate water supply is assured by a twelve acre surface reservoir made by damming a small creek.

The daily capacity of mine No. 4 is 1800 to 2000 tons, and about 550 men are employed. Number 4 is one of the best and most finely equipped mines in this part of the state.

Central Iowa Fuel Company Mine No. 2.—This mine is located at the village of Tipperary, in the western central part of the southwest quarter of section 22, Pleasant township. It is located in a small valley tributary to North Cedar creek. Its curb is about 880 feet above sea level. A spur track reaches it through

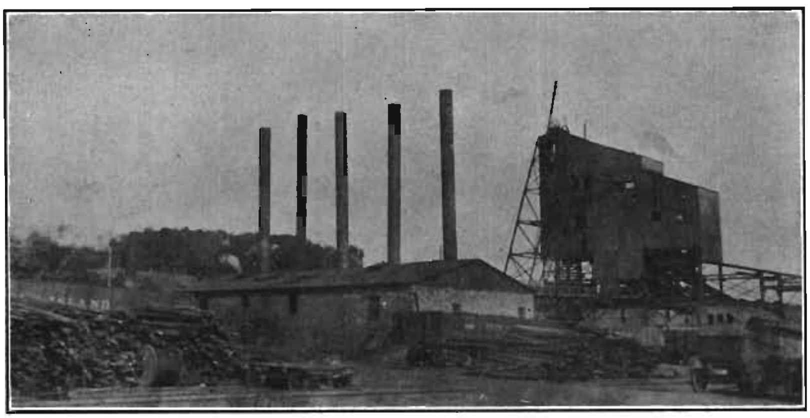


FIG. 29.—Central Iowa Fuel Company mine No. 2.

North Cedar creek valley from the southwest. Number 2 was opened in the spring of 1914 and is still an important producer. The Lower coal was reached a little above 700 feet above sea level and was found to be just a little over six feet thick at the bottom of the shaft. The thickness differs and runs up to eight feet in some rooms. The shaft is 180 feet deep but penetrates the coal body eccentrically so that the best coal in the basin lies west and northwest of the shaft. Drill section No. 7, page 149, gives in detail the strata passed through in this shaft, though the shaft was not sunk on this hole but from a somewhat lower elevation. The roof shales are almost identical with the roof in No. 4 and the bottom fire clay also is the same.

The methods of mining are essentially like those in use in Mine No. 4 except that no mining machines are employed yet. All of the coal is "shot off the solid". All three methods of underground haulage are employed. Mules gather the loaded cars from the rooms and concentrate them at points where electric locomotives pick up the short trains and concentrate them further at the end of the tail-rope. The trains of loaded cars are then hauled to the main shaft by the tail-rope and are there handled as in Mine No. 4. The distance that the trains are hauled by the tail-rope system is nearly 4000 feet and the operation is very efficient. Three electric locomotives and sixteen mules are in use underground.

Hoisting and surface handling is the same as in No. 4 and the rock waste is disposed of in the same way. The tipple is of steel and modern. Only three grades of coal are delivered to

FIG. 30.—Rock dump at mine No. 2, Central Iowa Fuel Company.

the cars: lump (six inches and up), egg (one and one-fourth inches up to six inches), and mine-run. The power equipment is much the same as at Mine No. 4 except in capacity. There are five boilers and water is obtained from North Cedar creek. The daily capacity of No. 2 is about 1000 tons and approximately 450 men are employed.

Central Iowa Fuel Company Mine No. 3.—Number 3 was opened up in 1916 and is located southwest of the center of section 32, Pleasant township, about one mile west of the village of Olmitz. Topographically it is situated similarly to Mine No. 2 and is served by the same railroad spur. The elevation of the curb is about 880 feet above sea level and the depth of the shaft is 160 feet. The Lower coal was reached 731 feet above sea level. The shaft is placed eccentrically to the best coal in the basin, which lies to the west. Drill section No. 11, page 225, gives the stratigraphic details of the Coal Measures for this general vicinity. The coal averages about the same thickness as in the

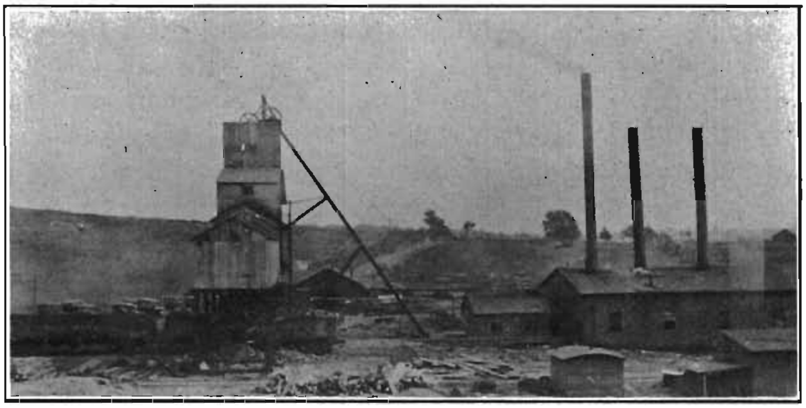


FIG. 31.—Central Iowa Fuel Company mine No. 3.

other mines above described, the roof is identical and the bottom is a little more sandy.

The methods of mining are the same as described above for mine No. 2. No mining machines are in operation and the coal is "shot off the solid". No electric locomotives are employed and haulage is done by mules and tail-rope. The tipple is of wood and is not strictly up-to-date. Only mine-run coal is delivered to the cars. An adequate supply of water is obtained from a strong spring in the valley half a mile west of the shaft. The source of the water is a sand and gravel pocket in the basal part of the glacial drift.

The daily capacity of No. 3 is about 600 tons and about 200 men are employed. This basin will soon be worked out and mine No. 3 may soon be abandoned.

The Central Iowa Fuel Company also operates a mine, known

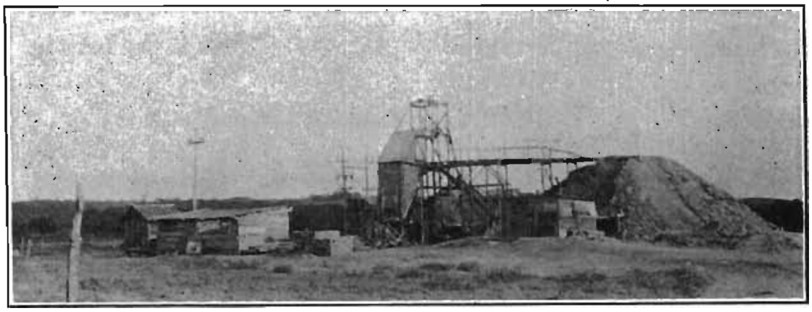


FIG. 32.—Daniels mine at Lucas

as No. 5, at Melcher in Marion county. The new mine to be opened in the No. 2 field probably will be known at mine No. 6.

The Daniels (Big Hill) Mine.—Mr. Evan Daniels has recently reopened the old Big Hill mine at Lucas and is working one of the upper coal veins, which is here two feet thick and lies at a depth of 99 feet. The elevation of the curb is about 900 feet above sea level. The detailed section is given in drill section No.

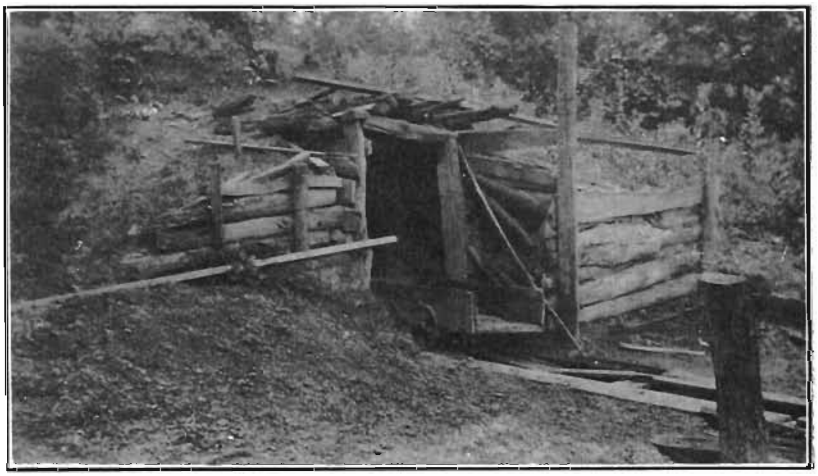


FIG. 33.—Drift mine in Swede Hollow, not in operation at the time of visit.

29, page 232. The present plant is very primitive and hoisting is done by a horse gin. The production amounts to only a few hundred tons a year. Four thousand tons have been taken out in three years. All of the coal is sold to local trade.

Drift Mines.—The only drift or wagon mines in operation in the summer of 1924 were four in number, all located in the northeast corner of Pleasant township. Some coal had been taken out of other banks in other parts of the county but these were not maintaining a trade. The location of each of the above four mines is as follows:

(1). NE. ¼ of SE. ¼ sec. 1, Pleasant township; coal at 770 feet above sea level.
(2). Middle of sec. 11, Pleasant township; coal at 790 (?) feet above sea level.
(3). SE. corner sec. 13, Pleasant township; coal at 775 (?) feet above sea level.
(4). NE. ¼ of NW. ¼ sec. 24, Pleasant township; coal at 780 feet above sea level.

The same stratum of coal is mined in all of the above mines and stratigraphically it ranges from thirty to sixty feet above the Lower coal mined in the mines of the Central Iowa Fuel Company. The coal is of fairly good quality though high in sulphur. In thickness it ranges from two to three feet and in places contains rather large amounts of rock or "bowlders", that split the seam. The bottom is of "fire clay" that is underlain by hard banded shale. The roof is of dark and red banded shale similar to the roof over the Lower coal. Water is not troublesome and on the whole the conditions for mining are favorable.

The equipment is in every case quite primitive. The coal is worked by the room and pillar system and haulage is done by hand, by hand windlass and by horse gin. In most cases the entry slopes downward slightly from the opening so that the grade is against the loaded car. In one instance, No. 1 above, a mule was used to pull the car through the main entry. The amount of coal loaded on a car differs but is never more than a few bushels and some cars carry only two bushels per load. In most cases a pump operated by a small gasoline engine removes the water. Ventilation in some of the very small drift mines is not especially provided for. In at least two of the above mentioned mines fresh air is forced into the more remote workings through stove pipes by small blower fans.

The combined production of these four mines amounts to a few hundred bushels a year and each mine employs, when it is working, from one to three men. The mines are owned by individuals and sell coal to a very local trade. If there were sufficient demand for the coal and adequate transportation facilities, this vein could yield quite a large amount of coal. Other surface veins in the county could likewise supply a large amount of coal if systematically worked.

An opening or hillside entry usually is not used for more than two or three years and more often only for a few months. Some coal is worked out within convenient reach of this entry and it is then abandoned and a new entry is made in a new location. In this way a hillside having a coal bed may have quite a number of abandoned mine openings. This practice is wasteful of much good coal that is not removed and whose subsequent removal is practically impossible. The coal thus left in the ground deterioriates to a large extent after the vein has been opened up.

A higher workable coal bed averaging about eighteen inches in thickness also is present in the general vicinity of the above mentioned mines. It is situated at a level ranging from fifty to seventy-five feet above the coal stratum above described. It has been "drifted" to some extent but has not been worked for a good many years. It is considered to be the same coal that outcrops in the creek bed near the middle of section 10, Pleasant township. In the latter location it rolls and pitches too much to be workable. This may be the coal worked at Dale's mine (location not definitely known) in the early days. The stratigraphy of the various coal beds has been discussed in a preceding chapter and the vicinities where drift mining has been carried on have been mentioned.

COAL ANALYSES AND TESTS

Volume XIX of the Iowa Geological Survey reports gives data relative to various tests and analyses of Iowa coals. Most of the tests were conducted at the United States Geological Survey's testing plant at St. Louis in connection with the Louisiana Purchase Exposition in 1904. In this volume data on coal from the Inland Coal Company's (now Central Iowa Fuel Co.) Mine No.

1 (now abandoned) are given. It is designated as "Iowa No. 5" coal. Extensive data on boiler tests conducted with this coal are given on pages 453 to 458 inclusive. These data are not repeated here.

The above volume, on pages 472 and 473, gives results on coking properties of "Run-of-mine" coal from Inland Mine No. 1. Nine thousand pounds of washed coal were burned for sixty-six hours but resulted in no coke. "Though this washed coal started off well in a hot oven, all that was gotten out of it was unburned coal mixed with pieces of charred coal and ashes." A further quotation states, "All of the Iowa coals tested are too high in sulphur to produce blast-furnace coke, and as the sulphur occurs largely as gypsum it can not be removed by washing. The ash also is high in relation to the fixed carbon."

A washing test on the same coal gave the results below:

	Car sample	Washed coal for coking test
Sulphur, per cent	3.19	2.28
Ash, per cent	12.63	7.93

Five tons of coal were used and the washing resulted in reducing the impurities as shown above.

Chemical analyses of Iowa coals are given in the same volume on pages 476 to 519 inclusive. Analyses of Lucas county coals are given on pages 504 and 505. Some of the same analyses are given in the above volume on page 416 in connection with "The Fuel Values of Iowa Coals." The analytical results are given in the accompanying tables taken from the above sources.

Localities	Moisture	Total Combustibles	Ash	Volatile Combustible Matter	Fixed Carbon	Coke Fixed Carbon plus Ash	Sulphur			Calorimetry B.T.U.	Authority
							In Sulphides	In Sulphates	Total		
Cleveland mine at Cleveland—Top of seam	9.95	80.27	9.72	37.70	42.57	52.35	3.69	.07	3.76		G. E. Patrick
Same—Middle of seam	9.39	84.21	6.43	38.62	45.59	52.02	2.69	.06	2.75		Same
Same—Bottom of seam	7.46	82.11	10.43	36.99	45.12	55.55	2.97	.07	3.04		Same
Same—Average	8.92	82.14	8.88	37.77	44.43	33.30	3.11	.07	3.18		Same
Lucas mine at Lucas Average	11.29	79.88	8.83	37.13	42.69	51.52	2.89	.08	3.97		Same
Inland Fuel Co. mine No. 1 Lump Coal	15.30	71.80	12.60	30.40	41.40				3.19	10,242	Iowa State College
Same, mine sample No. 1	18.69	73.58	7.73	31.80	41.78				2.39	10,505	N. W. Lord
Same, mine sample No. 1 Air dried	10.25	81.22	8.53	35.10	46.12				2.64	11,596	Same
Same, mine sample No. 2	18.59	74.26	7.15	34.36	39.90				3.10		Same
Same, mine sample No. 2, Air dried	12.37	79.93	7.70	36.98	42.95				3.34		Same
Same, car sample Run-of-mine	15.39	71.98	12.63	30.49	41.49				3.19	10,242	Same
Same, Run-of-mine Air dried	9.22	77.23	13.55	32.71	44.52				3.42	10,989	Same
Same, Washed	19.25	72.82	7.93	31.07	41.75				2.28		Same
Same, Washed, Air dried	13.45	78.05	8.50	30.30	44.75				2.44		Same
Average of 5	9.40	81.73	8.87	37.65	44.08				3.34		Iowa State College

Additional analyses of Inland mine No. 1 coal used in boiler tests; same sources as above. Proximate analysis of fresh coal.

	Per cent of coal	Per cent combustible
Fixed carbon	38.83	55.01
Volatile matter	31.76	44.99
Moisture	16.01	....
Ash	13.40	....
	100.00	100.00
Sulphur, separately determined	3.09	

Ultimate analysis of dry coal

	Per cent of coal	Per cent of combustible
Carbon (C)	65.21	77.59
Hydrogen (H)	4.71	5.6
Oxygen (O)	9.12	10.85
Nitrogen (N)	1.33	1.58
Sulphur (S)	3.68	4.38
Ash	15.95	....
	100.00	100.00

Analysis of ash and refuse

Carbon, per cent	15.49
Earthy matter, per cent	84.51

The following analyses are new, from car samples collected from fresh coal just loaded. The samples were collected from Central Iowa Fuel Company's Mines No. 2 and No. 4 by the writer in the summer of 1924. The authority for the analyses is Prof. H. L. Olin, Department of Chemistry, State University of Iowa.

Proximate Composition

	Mine No. 2 per cent	Mine No. 4 per cent
Loss on air drying	14.63	14.89
Composition dry basis		
Ash	7.80	12.25
Fixed carbon	51.00	46.40
Volatile matter	41.20	41.30
Sulphur	2.77	1.52
Thermal value	12,977 B.T.U.	12,500 B.T.U.

For comparison an average analysis of Iowa coals is here given, taken from volume XIX, Iowa Geological Survey, page 519. The authority for these figures is given as the Iowa State College Engineering Experiment Station.

	Per cent
Moisture	13.16
Carbon, volatile	33.36
Carbon, fixed	39.69
Ash	13.76
Sulphur	4.65
Calorific value (B.T.U.)	10,019 to 11,027

WATER AND CLIMATE

The water supply of Lucas county is entirely dependent on the rainfall. A portion of the rainfall evaporates, a second portion is surface run-off, and a third part settles into the ground as ground water. The first or evaporated portion is lost. The run-off supplies streams and reservoirs and is an important source of water supply. The part that soaks into the ground, the "cut-off", supplies the common wells and springs and in part the streams.

The distribution of precipitation and its amount, stated in inches, by months for a decade period, is given in the accompanying table. The average annual precipitation for this period is 32.62 inches. A second table gives the minimum and maximum monthly temperatures in Fahrenheit degrees for the same ten year period. The data are from the records of the U. S. Weather Bureau station located south of Chariton, in charge of Mr. C. C. Burr. The writer is indebted to Mr. Burr for his kindness and courtesy in making his records available.

The streams are important but not constant sources of water as many of them dry up in time of fairly prolonged drought. Most of the water for farm and village use is obtained from common dug or bored wells that are usually thirty to sixty feet deep. The shallower wells often "go dry" in the drier part of the summer, as the ground water level sinks below their depth. Many of the deeper wells penetrate to pockets of sand and gravel in the glacial drift and yield fairly constant supplies of water. Very shallow wells on the flood plains or valley flats of the larger streams yield a plentiful supply of water from the alluvium. This is especially true if the present stream has developed its valley in a subdrift valley, in which case the buried valley serves as an elongate reservoir for the ground water. This is true of the Chariton river valley.

In most places within the county the shales and sandstones of the Pennsylvanian strata are not water-bearing. It has been stated above that the mines are practically dry and coal prospect drill holes are usually dry except, as previously noted, in the vicinity of Lucas, hence the indurated strata are almost never looked to as sources of water. All water from the Coal Measures strata is highly corrosive and in many cases is sulphurous

Precipitation

	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	Average
January	.58	1.38	2.23	.45	.76	Trace	.44	.52	.85	.35	.756
February	.77	1.65	.68+	Trace	.86	2.20	.26	.41	1.65	.26	.874
March	3.19	1.12	1.42	1.80	.16	3.28	3.72	1.72	3.73	1.56	2.170
April	1.80	.82	2.86	6.53	2.62	5.88	7.04	4.42	1.73	1.64	3.534
May	.77	7.13	5.46	3.38	4.69	4.02	2.52	3.02	5.95	1.86	3.880
June	1.27	4.94	2.74	9.71	5.26	5.41	3.01	7.33	1.74	3.19	4.460
July	1.93	11.66	1.66	.52	1.33	4.98	5.17	2.90	7.46	1.70	3.931
August	2.13	4.09	2.83	2.68	5.45	2.53	1.87	5.07	4.14	5.17	3.599
September	10.74	7.42	2.02	4.13	2.68	6.92	6.00	9.34	2.22	3.31	5.478
October	1.88	.73	1.99	1.48	3.13	1.98	1.46	2.21	2.07	1.10	1.803
November	Trace	.78	2.79	Trace	1.76	3.26	1.50	.28	4.47	.68	1.552
December	.62	Trace	.67	.34	1.04	.28	1.41	.96	.10	.44	.586
Total	25.68	41.72	27.35	31.02	29.74	40.74	34.40	38.18	36.11	21.26	32.62

Temperature, Degrees F.

	1914		1915		1916		1917		1918		1919		1920		1921		1922		1923	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
January	–3	58	–22	55	–23	57	–12	55	–24	46	–21	61	–4	48	0	56	–4	52	–5	53
February	–11	46	6	57	–15	55	–23	55	–24	65	–2	63	–5	44	12	74	–5	64	–9	57
March	5	74	10	56	2	77	–5	80	9	78	–2	67	–2	75	12	76	19	66	–9	75
April	20	83	23	86	18	86	18	77	19	77	24	75	11	72	18	80	26	81	20	78
May	35	92	30	92	31	85	29	86	30	88	35	84	37	85	32	91	43	84	29	82
June	45	97	37	85	41	91	39	92	47	96	41	90	51	92	52	93	45	93	47	97
July	51	105	45	87	56	100	51	102	46	100	55	98	53	94	53	95	50	90	55	98
August	48	99	37	87	46	103	45	98	47	110	52	95	52	91	51	96	51	99	43	96
September	42	91	35	87	26	97	38	85	28	83	40	94	32	88	38	96	42	94	34	86
October	18	80	23	80	18	89	10	75	26	86	14	85	23	86	27	85	25	87	17	77
November	0	74	13	78	–3	76	11	74	6	70	5	58	8	67	12	66	23	69	16	70
December	–18	55	1	52	–21	62	–22	56	0	58	–20	49	–5	58	–6	62	–6	64	–13	57
Extremes	–18	105	–22	92	–23	103	–23	102	–24	110	–21	98	–5	94	–6	96	–6	99	–13	98

as well and so is not especially desirable even if it is available. The well drilled by Mr. J. S. Eaton in 1900 in Otter Creek township penetrated over 100 feet of sandstone but got almost no water and the hole was abandoned. The record of this well is reported in drill section No. 30, page 166 of this report.

Hillside or gravity springs are common but not plentiful and are good sources of water in just a few places. A large spring supplies water for the boilers at Central Iowa Fuel Company mine No. 3. In this case the water comes from a pocket of glacial gravel lying in a slight depression on the Coal Measures surface. The shales are practically impervious and most of the springs in the northeastern part of the county occur at the base of the drift. At other places water contained in pockets of sand and gravel in the drift gives rise to springs and seeps on the hillsides. Many of the springs are more or less intermittent. Some of the larger springs of the county are listed below:

Hanna Kent farm, three miles west of Lucas;

J. M. Taylor farm, three and a quarter miles north of Derby;

George Johnson farm, five miles northeast of Russell.

No wells which have ever been drilled in this county reach the deep artesian aquifers, as the St. Peter or Jordan sandstones. It has been shown in a preceding part of this report (p. 131) that the St. Peter should be reached at 800 to 1000 feet below sea level, the lower level being attained in the western part of the county. In the vicinity of Chariton it could be expected at a depth of about 2050 feet, from a surface elevation of 1040 feet above sea level. Even if wells were drilled into these aquifers there is a strong probability that the sandstone would be too tightly cemented to furnish an adequate amount of water. The water also might prove to be too highly mineralized to be palatable or suitable for use in boilers. This has been the experience with some of the deep wells in neighboring counties. These probable difficulties render the drilling of an artesian well as a source of water in this part of the state a rather uninviting gamble. J. L. Tilton has discussed the deep well problem for Clarke county in his report on The Geology of Clarke County [28] and the facts there presénted are in the main thought to be applicable to Lucas county. The deep wells of neighboring counties are discussed

[28] Iowa Geol. Survey, vol. XXVII, pp. 107-169; "The Deep Well Problem for Clarke County," pp. 158-162.

and the detailed records are given in volume XXI of the Iowa Geological Survey. Reference has been made previously to some of these in the discussion of the Paleozoic strata.

The table below gives data of typical wells in Lucas county as reported in "Underground Waters of the South-Central District" of Iowa, in volume XXI, Iowa Geological Survey, page

Typical wells of Lucas County.

Owner	Location	Depth	Depth to rock	Source of supply	Remarks: (Logs given in feet)
		Feet	Feet		
T. 72 N., R. 21 W. (Lincoln)					
A. Culbertson	NE. 1/4 sec. 18	342	94	Drift sand; sandstone (DesMoines).	Clay, 10; sand and gravel, 84; Coal Measures, 248.
D. G. Bennett	SE. 1/4 sec. 24	304	70	Drift sand	Loess, 10; drift, 60; Coal Measures, 234.
J. A. Slattengren	SW. 1/4 sec. 23	324	65	do	Clay, 50; sand, 15; Coal Measures, 259.
L. C. Whitten	NE. 1/4 sec. 13	131	17	Sandstone (Des Moines).	Drift, 17; Coal Measures. 114.
J. M. Cowan	NW. 1/4 sec. 8	174	22	Drift sand	Clay, 11; sand, 11; Coal Measures, 152.
C. G. Erickson	NE. 1/4 sec. 2	148	21	Sandstone (Des Moines).	Clay, 18; sand, 3; Coal Measures (with 45 feet of sandstone at base). 127.

955. In the same report and on the same page a composite well section in and about the village of Russell is given as follows:

Composite Well Section Near Russell

	THICKNESS IN FEET
Soil and loess	8 to 20
Subloessial sand; scanty water.	
Yellow till (Kansan)	9 to 30
Gravel at base of Kansan till; water bearing.	
Clay, blue	10 to 60
Coarse sand and gravel; much water.	
Coal shales.	

One of the most important sources of water supply in Lucas county is the "run-off" water, which is conserved behind dams in reservoirs. These are made possible by the fact that much of the glacial drift clay is tight enough to make a nearly impervious bottom. The reservoirs on some of the stock farms are from an acre to three or four acres in areal extent. Some of these reservoirs are so fortunately situated that the feeding streams receive spring water during most of the dry season and do not dry up or become so stagnant as do those that receive only run-off water. From a sanitary point of view some of these ponds, particularly those of the latter class, are very unsatisfactory, especially during times of prolonged drought.

The larger reservoirs, as those of the Chicago, Burlington and Quincy Railroad and the city of Chariton, are fed to some extent by springs and have an areal extent of 100 acres or more. They are supplied by the run-off from a catchment basin of two or three square miles. The water is soft and especially suitable for boiler use and after chlorination is safe for household use. Reference has been made also to the surface reservoir that supplies water for the boilers at Central Iowa Fuel Company mine No. 4. It has an areal extent of twelve acres and has been very satisfactory.

The adequacy of the surface reservoir system of water supply is dependent on the amount of rainfall and its distribution throughout the year. The rainfall seems to be adequate in Lucas county and reference to the precipitation table shows on the average a very satisfactory distribution. This combination of favorable conditions does not seem to prevail to the same extent in counties farther west.

Chariton water supply.—Prior to 1906 the city of Chariton (population 5,175) had no central water supply and depended on wells and cisterns for its water. Many wells are still in use. Between 1906 and 1915 the public water supply was drawn from several shallow wells dug in the alluvial deposits underlying the bottom lands along Chariton river southwest of the city, in the vicinity of the present ball park. The well curbs were about 90 feet below the upland levels. The water was pumped from these large wells into an elevated tank with a capacity of 100,000 gallons, from which it was distributed through about seven miles of mains. The same tank and mains are still in use with the present system. It was a hazardous thing, from the sanitary point of view, to use such large quantities of water from shallow wells which received much of their supply from water draining from under the city itself. It became apparent by 1915 that the city needed a safer, larger and more reliable water supply and the present reservoir system was then put into operation.

The reservoir is located nearly three miles east of the courthouse square, in section 27, Lincoln township, on Little White Breast creek. The areal extent of the body of water varies from 70 to 100 acres. About 240 acres of ground are owned by the city. The areal extent of the catchment basin is nearly 1800 acres. The capacity of the reservoir is 300,000,000 gallons when it is full to the top of the spillway. It is thought that this capacity with the present rainfall will be adequate even with a considerable increase in population.

The filtering and purifying plant and the pumps are located at the reservoir. There are two 100,000 gallon settling basins that are used alternately, morning and afternoon. The water enters these basins by gravity and is aërated as it enters. At the same time, during aëration, lime and "sugar of iron" are introduced. These form a gelatinous precipitate which removes suspended matter on settling. From the settling basins the water passes downward through filters into a "clear well" of 100,000 gallons capacity. The filters are made up of fine white sand at the top, very coarse sand below this and very coarse gravel at the bottom. There are four filters and they are used in pairs. Each pair of filters is washed every other day by passing water up through them. The clear filtered water is pumped from the clear well to the city tank; at the same time the chlorine gas is introduced by suction at the pumping station.

On the average about 300,000 gallons of water are used daily. About 300 pounds of chlorine, four tons of hydrated lime and a little more than 2600 pounds of "sugar of iron" are used annually. A pressure of about sixty pounds per square inch is maintained in the mains, which are connected to about seventy fire hydrants.

The Chicago, Burlington and Quincy Railroad has a large reservoir which is similar to the Chariton reservoir and is located west of the city of Chariton, mostly in section 24, White Breast township. It receives the run-off from an area of about three square miles. In addition to its water supply functions, the grounds surrounding the lake, "Crystal Lake," are used by local associations for a golf course and bathing beach. This is possible through the generosity of the Chicago, Burlington and Quincy Railroad.

The Chicago, Rock Island and Pacific Railway has a reservoir lying mostly in section 25, English township. Its catchment basin is a little less than two and a half square miles.

SOILS AND SOIL CONSERVATION

The soils constitute the most important economic asset of the county, for it is essentially an agricultural area. Soil is that part of the surficial material that supports plant growth and contains more or less humus. The depth to which sampling is done, in making soil maps, is about forty-two inches, the upper six to twelve inches being the surface soil and the remainder the subsurface and subsoils.

The formation of soil is a slow process. "Year by year the growing roots penetrate the earth, separating the portions mechanically by their growth, absorb mineral constituents dissolved from the ground, then, decaying, form humic acids which aid in the decomposition of mineral matter for plant food and furnish products of decay to darken the mixture and enrich it for further plant growth. The freezing and thawing of the ground aids in loosening the soil, allowing air to penetrate more readily. Moisture from below rises to the surface by capillary action, supplying depleted moisture in the summer time and replenishing mineral food in the soil. Ants and earthworms further aid in rendering the soil porous and then add their decaying bodies to enrich the humus. Ground squirrels, gophers and larvae of beetles also contribute their labors, though the sum total of their endeavors, especially of the last two, seems more harmful than useful to man. To these agencies are added the work of those numerous bacteria that cause decay, and particularly those on the roots of leguminous plants (clover, especially) that take nitrogen from the air and convert it into forms that are later taken up by the corn and wheat in the production of nitrogenous food. It is evident that good soil, formed by such slow acting agencies, even though assisted by fertilizers and labor and conserved by the rotation of crops, is an asset that should be guarded as carefully as possible, and not allowed to deteriorate nor to wash out in newly forming trenches.''

The above quotation is taken from The Geology of Clarke County, by J. L. Tilton, previously cited. The soil characteristics and soil types given below are quoted from the Soil Survey Reports of the Iowa Soil Survey.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into the soil survey work from this source is very small and need cause little concern.

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Agricultural Experiment Station in its Soil Report No. 1:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical or mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

Organic matter	All partially destroyed or undecomposed vegetable and animal materials.
Inorganic matter	Stones—over 32 mm.* Gravel—32—2.0 mm. Very coarse sand—2.0—1.0 mm. Coarse sand—1.0—0.5 mm. Medium sand—0.5—0.25 mm. Fine sand—0.25—0.10 mm. Very fine sand—0.10—0.05 mm. Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of soils:‡

Peats—Consisting of 35 per cent or more of organic matter, sometimes mixed with more or less sand or soil.

Mucks—25 to 35 per cent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 30 per cent clay, usually mixed with much silt; always more than 50 per cent silt and clay.

Silty Clay Loams—20 to 30 per cent clay and more than 50 per cent silt.

Clay Loams—20 to 30 per cent clay and less than 50 per cent silt and some sand.

Silt Loams—20 per cent clay and more than 50 per cent silt mixed with some sand.

Loams—Less than 20 per cent clay and less than 50 per cent silt and from 30 to 50 per cent sand.

Sandy Clays—20 per cent silt and small amounts of clay up to 30 per cent.

Fine Sandy Loams—More than 50 per cent fine sand and very fine sand mixed with less than 25 per cent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 per cent.

Sandy Loams—More than 25 per cent very coarse, coarse and medium sand; silt and clay 20 to 50 per cent.

Very Fine Sand—More than 50 per cent fine sand and less than 25 per cent very coarse, coarse and medium sand, less than 20 per cent silt and clay.

Fine Sand—More than 50 per cent fine sand and less than 25 per cent very coarse, coarse and medium sand, less than 20 per cent silt and clay.

Sand—More than 25 per cent very coarse, coarse and medium sand, less than 50 per cent fine sand, less than 20 per cent silt and clay.

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* 25 mm. equals 1 in. †Bur. of Soils Field Book. ‡Loc. cit.

Coarse Sand—More than 25 per cent very coarse, coarse and medium sand, less than 50 per cent of other grades, less than 20 per cent silt and clay.

Gravelly Loams—25 to 50 per cent very coarse sand and much sand and some silt.

Gravels—More than 50 per cent very coarse sand.

Stony Loams—A large number of stones over one inch in diameter.

Lucas county lies in the "Southern Iowa Loess" soil area, as defined by the Iowa Soil Survey. The loess is the geologic basis for most of the soil in the county. The glacial drift constitutes the basis for much of the soil on the valley slopes where the loess has been removed. Coal Measures shales form the basis of soil in only a small part of the area, mostly in Pleasant township, and at other more or less isolated places. Alluvial soils occur principally in the valleys of Chariton river, White Breast creek and North Cedar creek. The gumbotils are usually so limited in the areal extent of their exposures that they are not important in a general consideration of the soils.

The loess and glacial drift soils are rich and productive except on hillsides where erosion prevents the retention of an adequate humus. In such places the soluble materials are quite readily leached out. The small patches of gumbotil are impervious to water, hard to work when either wet or dry, and are lean in soluble plant food. The shales are usually exposed on slopes that because of the topography wash badly and so they do not constitute the basis of very much good soil. Fortunately the areas of these latter two types are small. The alluvial soils are deep and fertile but are subject to overflow in time of heavy rainfall; for this reason they are used largely for grazing.

No soil map or soil report has been published for Lucas county but the Iowa Soil Survey Report No. 19 covers Wayne county, adjoining on the south. In-as-much as the geology and topography of the two counties are much alike over considerable areas almost identical soils may be expected in similar situations. Certain types of soils have been defined and described by the Iowa Agricultural Experiment Station and by the Federal Department of Agriculture. These types are closely adhered to in all of the soil reports and on the maps. It is not the purpose here to restate these definitions and descriptions but only to refer to the types that are likely to be found in Lucas county. For more complete information on these soil types the reader is referred to the Soil Survey Reports and particularly to No. 19, on Wayne county.

The Grundy silt loam, a loess soil, covers the extensive Kansan upland areas in Wayne county and this type no doubt persists over the flat uplands widely distributed in Lucas county. The surface soil of this type is "a dark grayish-brown to nearly black silt loam extending to a depth of 8 to 10 inches." A second type of loess soil, the Grundy clay loam, occurs associated with the Grundy silt loam in depressed areas that are not so well drained. In Wayne county the Shelby loam, a drift soil, occurs on the slopes "intermediate between the bottom-land soil and the more level uplands occupied by the Grundy silt loam." It should be similarly situated over a large part of Lucas county. Likewise the Wabash silt loam and the Wabash clay loam should occur over the alluvial bottomland flats. In the more maturely dissected part of the county, the northeast quarter, other types of soil also may occur. It is thought that such types occur as the Clinton silt loam, a loess soil typical of rough and broken topography; the Grundy silty clay loam; the Lindley silt loam, a drift soil; the Union silt loam, an indurated rock residual soil; and perhaps other minor types. These latter types are described in the Soil Survey Reports for Wapello county (No. 18) and Mahaska county (No. 29).

The tables which follow are self-explanatory and show the productiveness and the great value of the soils in this county.

Average yield per acre of crops for ten year period ending Dec. 31, 1919.[29]

CROP	BUSHELS PER ACRE
Corn	32.1
Oats	35.5
Spring wheat	15.3
Winter wheat	19.3
Barley	27.0
Rye	15.4
Potatoes	53.9
	TONS
Tame hay	1.33
Wild hay	1.07
Alfalfa	2.70

[29] Data taken from records of Iowa Weather and Crop Service.

Acreage and yield of principal crops for year 1922

CROP	ACREAGE	PER ACRE YIELD BUSHELS	TOTAL YIELD BUSHELS
Corn	52,410	47	2,463,270
Oats	22,557	28	631,596
Winter wheat	81,858	18	159,444
Spring wheat	21	15	315
Barley	42	28	1,176
Rye	187	10	1,870
Potatoes	94	67	6,208
Timothy seed	9,963		38,089
Clover seed	1,706		1,370
		TONS	TONS
Hay, tame	33,296	1.5	49,944
Alfalfa	138	2.2	304

Acreage Distribution[30]

	ACRES
Total area[31]	276,480
Total acreage of farms	258,463
Acreage occupied by farm buildings, highways, and feed lots	9,267
Acreage in crops not otherwise listed	920
Waste land	2,500

Farm tenure (1922)[32]

Number of farms	1,659
Average size, acres	156
Owners	968
Relative renters	219
Renters	312
Both own and rent	146
Unclassified	14

Live Stock, Jan. 1, 1923

Horses	7,769
Mules	1,191
Swine	49,792
Cattle	28,666
Sheep	14,252

Another problem of great importance is that of soil waste and erosion. This problem is extensively dealt with in numerous bulletins and pamphlets issued by the Iowa Agricultural Experiment Station and by the Federal Department of Agriculture. It is not the purpose to treat this problem at length in this place but certain outstanding facts should be mentioned.

Over half of the area of the county is in slope. The declivity of much of this is so great that running water erodes deeply into the hillsides even in times of small showers. Soil on slopes that wash easily accumulates very slowly and then only when protected by a forest and grass covering. When hillsides are denuded of their forest growth, as has been done over so much of

30 Statistics taken from Iowa Year Book of Agriculture (1922).
31 Total acreage as given by the Fourteenth Census (1920) in Bulletin—Agriculture: Iowa.
32 Statistics taken from Iowa Year Book of Agriculture (1922).

the area of Lucas county, the slopes are exposed to the eroding action of running water. In most cases the rich humus soil, accumulated through scores of years of time, is washed away in a single season. This is still further accelerated by cultivating the slopes. Slopes thus denuded of forest covering and soil become practically worthless.

Another result of forest denudation is that more of the rain water runs off during a shower and less is retained in the porous soil and vegetal cover than when the slopes are forested. This retention of rain water, that eventually becomes ground water, is important, for it feeds the streams and springs long after the surface has become dry. A forest and vegetal cover on the slopes insures a more continuous and even supply of spring and stream water in dry seasons. If the water all runs off rapidly the streams soon dry up and the springs diminish in size or dry up. The greater volume of water that runs off a denuded surface accentuates flood scour and flood damage.

At least 10 to 20 per cent of the area of the county should be carefully forested. Native trees should be grown and it is believed that the time will soon come, if it has not already, when slope land carefully forested and conserved will yield as lucrative financial returns as much of the better agricultural land. Such slope lands as still have a native stand of timber should be conserved in that condition. Replacement should keep pace with cutting and in a systematic way.

CLAYS

Good workable clays exist in Lucas county in abundance but have not been utilized. About a score of years ago some efforts were made to manufacture brick and tile from the drift and loess clays. The industry failed, through no lack of efficiency of the methods used or for any deficiency in the clays, but for lack of a market for the products. Loess, drift and gumbotil clays exist widespread over the county in great abundance and of as good quality as any similar clays elsewhere. If a demand existed for common brick and tile or railroad ballast, unlimited quantities of these could be produced almost anywhere within the county. Fuel in the form of coal exists in abundance near at hand.

The Coal Measures shales and clays are abundant and offer a very wide range of choice of individual clays as well as possibilities for many combinations among themselves and with the glacial and loess clays. Some of the under clays or so-called "fire clays" are very pure, are available in quantity and are suitable for pottery. Many of these fire clays singly or in combination with other local clays should make excellent stone ware. Some are very free from iron and other objectionable constituents. A few beds of clay are ocherous and one such bed was noticed in particular on the Wm. Ainsley farm east of the town of Lucas.

With the combination of raw materials, clay and coal, that exists in this county a large ceramic industry with a wide range of products could thrive if it had a good market. The clays are an important potential economic resource. Beyer and Williams noted the existence of these clays in Lucas county in their report on The Geology of Iowa Clays, Iowa Geological Survey, volume XIV, page 447.

GRAVEL AND SAND

Gravel and sand in usable quantities are exceedingly rare. It is quite a striking fact that the streams and even the smaller creeks have such meager amounts of sand and gravel in their channels that it is insufficient to supply the most local demands. The beds of most of the streams are muddy and not sandy. Pockets and small beds of gravel and sand lie buried in the glacial drift, as has been noted already in connection with water supply, but they are seldom exposed and in some cases are mixed with so much silt and clay as to be of little value. Quite a large quantity of such material is exposed in the valley of White Breast creek in the north middle to the north boundary of the county.

The glacial drift in the southwest part of Benton township contains a large amount of disseminated sand and gravel. In sections 8, 20, 21, 28 and 29 fairly large hills of sand and gravel exist. The overlying materials, loess and drift, have been eroded, leaving the heaps of porous sand and gravel. The amount of this material is very great, but the writer cannot vouch for its purity except at the surface. It is probable that below a comparatively shallow zone it may contain a large percentage of very fine silt and clay, which materials have been washed out of the superficial part. The material does not seem to have been put to any use; certainly no large quantity has ever been removed.

SANDSTONE AND LIMESTONE

Building stone of all kinds is very scarce and is available at only a few places and then is usually of very inferior quality. Such rock as is available has in the past been used only in laying crude foundations and for rough masonry. Practically all of the building stone used in the county for many years has been shipped in. Not a single quarry was open or showed any evidence of having been worked for a good many years, at the time of the writer's visit. The few valuable beds of building stone that do occur are in general so associated with other sedimentary strata as to render their utilization practically impossible. They lie, for the most part, low down in fairly deep valleys, with steep slopes above. They cannot be uncovered and stripped for more than a few feet to a few yards without removing enormous amounts of overburden. This does not pay, as the beds of limestone are almost nowhere over four feet thick and the sandstones are usually not more than ten feet in thickness, generally only two or three feet.

The best sandstone which was seen by the writer is exposed along a branch of Flint creek in the northwest quarter of section 10, Pleasant township. It is a lenslike bed about two feet in thickness, is light gray in color and weathers brown. It is very hard and is very nearly a quartzite. A considerable quantity of it could be taken out at moderate expense. Its stratigraphic relations are given in surface section No. 12, page 146. Other softer sandstone beds occur to the east in the same vicinity.

Nearly twenty feet of hard gray to brown sandstones and conglomerates outcrops in the hillsides in the northeast corner of section 15 and in the southeast corner of section 10, Pleasant township. These beds are of differing hardness, the conglomerate layers being very hard and cemented closely with silica. Considerable quantities of these rocks could be quarried. These strata are believed to belong to the Chariton conglomerate. The stratigraphic equivalents of the above beds are also well exposed through section 3 and in sections 22 and 27, Pleasant township. In the northwest quarter of section 3, Pleasant township, the stratigraphic section contains at least six even and uniform beds of usable sandstone from six inches to three feet in thickness. Some quarrying has been done in this vicinity. In the southeast quarter of section 22, Pleasant township, about six feet of hard conglomerate, a second bed of similar conglomerate two feet thick, and five feet of brown cross-bedded sandstone are exposed. The material is accessible as to quarrying but transportation from this place would be rather difficult.

A soft yellow sandstone has been quarried on a branch of Little White Breast creek in the northeast quarter of section 32, English township. At numerous points along Swede Hollow in Liberty and White Breast townships there is exposed a fairly soft yellowish brown sandstone that is massive for the most part and two to eleven feet thick. It has never been quarried to any great extent.

Limestones have been quarried principally at three localities in the past, but very little has been taken out during the last fifteen years. At the "Smith Quarry" on Long Branch creek, section 4, English township, a four foot bed of light gray limestone has been worked. It is overlain by buff limestone, from which it is separated by calcareous shale. It is said to have produced a high grade of quicklime and is a good resistant building stone which weathers white. A similar limestone has been quarried and burned for lime on Little White Breast creek two miles northeast of Chariton, in section 16, Lincoln township. A large amount of this rock has been used for foundations in Chariton and has stood up well. The stratum is nearly five feet thick and is separated into about three layers, which are massive for the most part. It is described in surface section No. 32. A two to three foot bed of dark gray limestone has been quarried to some extent in Swede Hollow and much of this rock also has been used in Chariton.

The local limestones do not occur in sufficient quantity nor are they accessible enough to be of use for agricultural lime. At no point could a quarry be opened and crushing machinery installed that could produce any great amount of crushed limestone at a reasonable price. The farmers of Lucas county must look for their supplies of agricultural lime from the outside. Mine dump materials are never sufficiently calcareous to be of any value when spread on cultivated land. Such mine waste is more apt to be positively harmful.

Brief mention of these quarry products has been made by

Beyer and Williams in The Geology of Iowa Quarry Products, Iowa Geological Survey, volume XVII, pages 475 to 476, and by Beyer and Wright in Road and Concrete Materials of Iowa, Iowa Geological Survey, volume XXIV, pages 416 and 417.

ROAD MATERIALS

Practically all road materials used in Lucas county must be "imported." The scarcity of gravel and sand has been pointed out and also the absence of workable beds of quarry rock has been noted. The resources are thus well known. The value of the clays for making brick and railroad ballast has been pointed out.

Mine dump waste as a road metal of some local value has been largely overlooked. The mine dumps contain coal and slack which on burning partly slag the clay and rock waste and this makes a fairly good road bed when it is kept in condition. A good many miles of secondary country road could be greatly improved with this available material and at no very great expense.

OIL

According to Howell[33] Lucas county lies in the area designated "area in which oil should not be expected." It can only be said with certainty that oil does not occur in the Des Moines or Pleistocene series within the county. The amount of coal prospect drilling done would have revealed it if it did. It is also believed that decomposing organic matter may form either coal or oil but not both in the same place at the same horizon. In the Des Moines series of central Iowa it formed coal, so gas or oil should not have been expected even if definite proof to the contrary were not at hand. No exact knowledge of the deeper formations is available nor is much known of the minor structures. In the absence of positive knowledge it is best to conclude that the probability of oil is extremely small. The Ordovician horizon would be the most promising and drilling would have to go at least to the St. Peter sandstone to yield definite proof, either positive or negative.

33 J. V. Howell, Petroleum and Natural Gas in Iowa: Iowa Geol. Survey, vol. XXIX, pp. 1-48.

ACKNOWLEDGMENTS

In the preparation of this report the writer has received aid from numerous people. Specific mention has already been made in the body of this report of the contributions of certain individuals. Individual mention cannot be made of every person who aided in one way or another. Special mention, however, is due The Central Iowa Fuel Company for the courteous and valuable help extended the writer through their engineer, Mr. F. W. Trost. Personal thanks also are due to Mr. Trost. The writer also very greatly appreciates the valuable aid given him by Doctor Lees, Assistant State Geologist, in the revision of the original manuscript.

APPENDIX

Supplementary Drill Sections

Drill section No. 1. Northwest corner of SW. ¼ of NW. ¼, sec. 12, Pleasant township.

Curb elevation 808 feet above sea level.

		THICKNESS Ft.	In.	DEPTH Ft.	In.
1.	Soil, alluvium	6		6	
2.	Sand, alluvium	20		26	
3.	Gravel, alluvium (?)	4		30	
4.	Hard light sandstone	2		32	
5.	Soft light sandy shale	2		34	
6.	Soft dark shale	8		42	
7.	Hard blue rock	2		44	
8.	Soft light shale	2	6	46	6
9.	Medium hard limy shale	2		48	6
10.	Hard light sandy shale	4	6	53	
11.	Medium soft dark shale	2		55	
12.	Hard light sandstone	2		57	
13.	Hard dark shale	1	6	58	6
14.	*Coal*		6	59	
15.	Medium light soft shale	9		68	
16.	Medium light hard shale	2		70	
17.	Medium light hard sandy shale	2		72	
18.	Medium light hard limestone (Ste. Genevieve)	12		84	

Total depth 84 feet.
Top of limestone 736 feet above sea level.
Bottom of hole 724 feet above sea level.

Drill section No. 2. Middle east side sec. 13 of Pleasant township.

Curb elevation 791 feet above sea level.

		THICKNESS Ft.	In.	DEPTH Ft.	In.
1.	Surface soil, may be alluvium	21	6	21	6
2.	Soft sandstone	1	6	23	
3.	Soft light shale	5		28	
4.	Soft dark shale	3		31	
5.	Soft light shale	3		34	
6.	Soft dark shale	5	6	39	6
7.	Hard dark rock		6	40	
8.	Hard dark sandstone		6	40	6
9.	Soft light shale	1	6	42	
10.	Soft light sandstone	15		57	
11.	Dark medium soft shale	12	6	69	6
12.	*Coal*, bony	1	3	70	9
13.	Fire clay	2		72	9
14.	Sandstone	3		75	9
15.	Soft dark shale, with sand balls	15		90	9
16.	Soft light shale	1		91	9
17.	Hard limy shale	11		102	9
18.	Hard light limestone (?) Top 700 feet above sea level	20		122	9
19.	Soft blue lime shale	1		123	9
20.	Hard light sandstone	3		126	9
21.	Hard light limestone	17	6	144	3

22.	Hard light sandstone	6		150	3
23.	Hard light limestone	4	6	154	9
24.	Hard light sandstone	9		163	9
25.	Hard light limestone	4		167	9

Total depth 168 feet.
Bottom of hole 623 feet above sea level.

Drill section No. 3. Near middle east side NE. ¼ sec. 22, Pleasant township.

Curb elevation 968 feet above sea level.

		THICKNESS	DEPTH
		Ft.	*Ft.*
1.	Yellow clay	35	35
2.	Blue clay, sand and bowlders	165	200
3.	Sand and clay	26	226
4.	Sandy shale reached at 226 feet.		

Total depth 226 feet.
Bottom of hole 742 feet above sea level.

Drill section No. 4. NE. ¼ of sec. 22, Pleasant township.

Curb elevation 948 feet above sea level.

		THICKNESS		DEPTH	
		Ft.	*In.*	*Ft.*	*In.*
1.	Soil, gray drift, blue clay and bowlders, 2 feet of sand 25 to 27 feet from top	104		104	
2.	Shale, gray, hard	49	9	153	9
3.	"Shoddy" (fissile shale)		1	153	10
4.	*Coal*, not "Lower"	4	3	158	1
5.	Brown bottom		2	158	3
6.	Fire clay	1	9	160	

Total depth 160 feet.
Top of coal (4) 794 feet above sea level.
Bottom of hole 788 feet above sea level.

Drill section No. 5. NW. ¼ of sec. 26, Pleasant township.

Curb elevation 805 feet above sea level.

		THICKNESS		DEPTH	
		Ft.	*In.*	*Ft.*	*In.*
1.	Surface soil } May all be alluvium	9		9	
2.	Sand and gravel } May all be alluvium	26		35	
3.	Shale, soft, light	6		41	
4.	Shale, medium dark to dark	3		44	
5.	*Coal*, soft, "rotten"	1	3	45	3
6.	Rock (may be "bowlder")	1	1	46	4
7.	*Coal* (good) "Lower", mined at mine No. 2	3		49	4
8.	Fire clay, soft	1	2	50	6
9.	Shale, light, soft	14		64	6
10.	Shale, light, soft (limestone nodules)	5		69	6
11.	Shale, variegated, medium soft	14		83	6
12.	Sandstone, soft, with shale partings	43		126	6
13.	Sandstone, coarse, medium soft, medium light	14		140	6
14.	Shale, green, with limestone nodules	2		142	6
15.	Shale, medium hard, variegated	10		152	6
16.	Shale, medium hard, limy	3		155	6
17.	Limestone, hard (may be Mississippian)	1		156	6

Total depth 156 feet, 6 inches.
Top of Lower coal 761 feet above sea level.
Bottom of hole 647 feet above sea level.

Drill section No. 6. Middle NE. ¼ of SW. ¼ sec. 27, Pleasant township.
Curb elevation 818 feet above sea level.

		THICKNESS Ft.	DEPTH Ft.
1.	Surface soil	10	10
2.	Sand	25	35
3.	Sand and coarse gravel	5	40
4.	Soft light shale	3	43
5.	Streaked sandy shale	7	50
6.	Soft medium dark streaked sandstone	20	70
7.	Soft medium dark streaked sandy shale	66	136
8.	Streaked sandy shale	12	148
9.	Sandstone	2	150
10.	Medium dark medium soft streaked sandy shale	44	194
11.	Medium dark to medium light shale	23	217
12.	Medium dark medium soft banded shale	51	268
13.	Dark medium soft shale	5	273
14.	Dark medium soft sandy shale	4	277
15.	Limestone (Miss. ?)	1	278

Total depth 278 feet.
Bottom of hole 540 feet above sea level.

Drill section No. 8. Middle east side SW. ¼, sec. 20, Pleasant township.
Curb elevation 933 feet above sea level.

		THICKNESS Ft.	THICKNESS In.	DEPTH Ft.	DEPTH In.
1.	Soil, loess	24		24	
2.	Sand and clay, drift	69		93	
3.	Soft clay shale	2		95	
4.	Soft light shale	4		99	
5.	Medium soft dark shale	2		101	
6.	*Coal*, rotten		4	101	4
7.	Soft light shale	11	8	113	
8.	Soft sandstone	3		116	
9.	Hard limestone	2		118	
10.	Hard medium dark shale	5		123	
11.	*Coal* (May be No. 7 of Columnar Section)	2		125	
12.	Fire clay	2		127	
13.	Medium light sandy shale	12		139	
14.	Dark sandy shale with banded sand streaks	83		222	
15.	*Coal* (Lower)	6	3	228	3
16.	Hard dark shale		3	228	6
17.	Medium hard sandy fire clay	5	6	234	

Total depth 234 feet.
Top of Lower coal 711 feet above sea level.
Bottom of hole 699 feet above sea level.

Drill section No. 9. Record at probable location of new shaft. North center of NE. ¼, sec. 20, Pleasant township.
Curb elevation 917 feet above sea level.

		THICKNESS Ft.	THICKNESS In.	DEPTH Ft.	DEPTH In.
1.	Soil, clay and drift	65		65	
2.	Shale, mixed	15		80	
3.	Shale, gray	20		100	
4.	Shale, light gray, mixed	15		115	
5.	*Coal*	1		116	
6.	Shale, gray, slaty	73		189	
7.	Shoddy top	1		190	
8.	*Coal* (Lower)	5	3	195	3
9.	False bottom		3	195	6
10.	Fire clay	2	1	197	7

Total depth 197 feet, 7 inches.
Top of Lower coal 727 feet above sea level.
Bottom of the hole about 719 feet above sea level.

Drill section No. 10. Southeast corner of NW. ¼ of SE. ¼ of sec. 29, Pleasant township.

Curb elevation 928 feet above sea level.

		THICKNESS Ft.	DEPTH Ft.
1.	Surface clay	28	28
2.	Sand and clay	90	118
3.	Soft dark shale	2	120
4.	Soft variegated shale	8	128
5.	Hard sandstone	5	133
6.	Soft medium dark shale	15	148
7.	Medium light shale	10	158
8.	Medium dark shale	2	160
9.	Medium hard medium dark streaked sandy shale	54	214
10.	Medium hard medium dark sandy shale with sandstone partings	46	260
11.	Light sandstone	4	264
12.	Medium dark medium hard shale with sandstone partings	23	287

Total depth 287 feet.
Bottom of hole 641 feet above sea level.

Drill section No. 11. Center section 32, Pleasant township.

Curb elevation 895 feet above sea level.

		THICKNESS Ft.	In.	DEPTH Ft.	In.
1.	Soil, probably loess	20		20	
2.	Clay and sand, drift	48		68	
3.	Soft dark shale	1		69	
4.	*Coal* (May be No. 11 of Columnar Section)		9	69	9
5.	Fire clay		3	70	
6.	Soft light shale	5		75	
7.	Mixed soft variegated shale	2		77	
8.	Medium soft sandstone	5		82	
9.	Soft dark shale	12		94	
10.	*Coal* (May be No. 7 of Columnar Section)		6	94	6
11.	Sandy fire clay	1	6	96	
12.	Medium soft sandstone	9		105	
13.	Hard gray rock	4		109	
14.	Medium soft dark sandy shale	1		110	
15.	Medium dark and medium hard shale. Some sand	54	6	164	6
16.	*Coal* (Lower)	5	4	169	10
17.	Light medium hard very sandy shale	6	2	176	
18.	Hard gray rock with sandstone partings	12		188	
19.	Soft light sandstone	28		216	

Total depth 216 feet.
Top of coal (16) 731 feet above sea level.
Bottom of hole 679 feet above sea level.

Drill section No. 12. 400 feet east of the middle of west side of NW. ¼, sec. 5, Cedar township.

Curb elevation 854 feet above sea level.

		THICKNESS Ft.	In.	DEPTH Ft.	In.
1.	Clay, alluvium	20		20	
2.	Sand, alluvium	4		24	
3.	Gravel, alluvium	2		26	
4.	Hard gray rock	1		27	
5.	Soft light shale	6		33	
6.	Soft variegated shale	7		40	
7.	Soft dark shale	2		42	

8.	Soft light shale	6		48	
9.	Soft light sandy shale	8		56	
10.	Soft light shale	3		59	
11.	Soft light sandstone	4		63	
12.	Hard medium dark shale	3		66	
13.	Hard blue rock	2		68	
14.	Hard medium dark shale	10		78	
15.	*Coal*	2	5	80	5
16.	Hard medium light shale	1	7	82	
17.	Hard light sandstone	15		97	
18.	Hard medium light sandy shale	7		104	
19.	Hard medium dark shale with sand streaks	37		141	
20.	Sandstone	14		155	

Coal should have come in just above No. 20
Total depth 155 feet.
Bottom of hole 699 feet above sea level.

Drill section No. 13. 750 feet east of west side of section along north side of SW. ¼ of SW. ¼ of sec. 6, Cedar township.

Curb elevation 867 feet above sea level.

		THICKNESS Ft.	In.	DEPTH Ft.	In.
1.	Surface clay, alluvium	14		14	
2.	Sand, alluvium	6		20	
3.	Soft light shale	4		24	
4.	Soft variegated shale	3		27	
5.	Light hard limestone		6	27	6
6.	Soft dark shale	4		31	6
7.	*Coal*		6	32	
8.	Soft light mixed shale	9		41	
9.	Light medium soft sandstone	8		49	
10.	Medium soft variegated shale	5		54	
11.	Dark medium soft shale	7	3	61	3
12.	*Coal*	1	6	62	9
13.	Soft light shale	3	3	66	
14.	Light medium soft sandy shale	3		69	
15.	Medium hard dark shale	13	5	82	5
16.	Hard blue rock		7	83	
17.	Medium dark medium hard shale	7	3	90	3
18.	*Coal* (Lower)	2	9	93	
19.	Light medium hard sandstone	32		125	
20.	Medium soft variegated sandstone	5		130	
21.	Soft light fine sandstone	26		156	
22.	Soft light coarse sandstone	78		234	
23.	Light green limy shale	4		238	

No. 23 is very close to the Mississippian.
Total depth 238 feet.
Top of Lower coal (18) 777 feet above sea level.
Bottom of hole 629 feet above sea level.

Drill section No. 14. 483 feet east of NW. corner of sec. 7, Cedar township.

Curb elevation 980 feet above sea level (?)

		THICKNESS Ft.	In.	DEPTH Ft.	In.
1.	Drift	104		104	
2.	Shale, gray and fine textured	11	6	115	6
3.	*Coal*	1	8	117	2
4.	Fire clay	7	10	125	
5.	Blue shale	10		135	
6.	Blue gritty shale	12		147	
7.	Dark blue fine textured shale	5		152	
8.	Black fine textured shale	1	6	153	6

9.	Blue gritty fine textured shale with lime nodules	16	6	170	
10.	Blue-gray fine textured shale	13		183	
11.	Black fissile shale	5		188	
12.	Blue soapy shale, gritty inclusions	8		196	
13.	Black soapy fissile shale	5		201	
14.	Dark gray fine textured shale	9		210	
15.	Sandstone and shale, micaceous	40		250	
16.	Black soapy shale with linguloid shells	10		260	
17.	Blue shale and mixed clays	125		385	
18.	Limestone (Mississippian)	55		440	
19.	Sandstone	1		441	

Total depth 441 feet.
Mississippian limestone 595 feet above sea level.
Bottom of hole 539 feet above sea level.

Drill section No. 16. NE. corner sec. 2, Lincoln township.

Curb elevation 1030 feet above sea level.

		THICKNESS Ft.	In.	DEPTH Ft.	In.
1.	Soil and clay (loess and gumbotil)	38		38	
2.	Sand	50		88	
3.	Gravel	4		92	
4.	Soft medium light shale	2		94	
5.	Medium soft medium light shale	15		109	
6.	*Coal*	1		110	
7.	Soft medium light shale	3		113	
8.	Hard medium dark shale	5		118	
9.	Medium light sandy shale	5		123	
10.	Hard medium dark shale	7		130	
11.	*Coal*	1	6	131	6
12.	Fire clay	2	6	134	
13.	Soft medium light calcareous shale	7		141	
14.	Limestone		8	141	8
15.	Medium light sandy shale	7	4	149	
16.	Hard medium dark shale	6		155	
17.	*Coal*		6	155	6
18.	Fire clay	1	6	157	
19.	Medium light sandy shale, lime concretions	7		164	
20.	Variegated shale	7		171	
21.	Hard medium dark shale	4		175	
22.	*Coal*		6	175	6
23.	Soft medium light shale	6	6	182	
24.	Limestone		8	182	8
25.	Medium hard medium light shale	3	4	186	
26.	Medium hard dark shale	4		190	
27.	Hard variegated shale	4		194	
28.	Medium hard medium dark shale	3	6	197	6
29.	Soft light shale	4		201	6
30.	Soft variegated shale	6		207	6
31.	Medium hard medium light sandy shale	12		219	6
32.	Sandstone	6	6	226	
33.	Soft medium dark shale	4		230	
34.	*Coal*		11	230	11
35.	Hard medium dark shale	10	1	241	
36.	Medium dark sandy shale	5		246	
37.	Sandstone	3		249	
38.	Hard medium dark shale (sandy streaks)	9		258	
39.	Sandstone	4		262	
40.	Hard medium dark shale	1		263	
41.	Soft light sandstone (Lower coal horizon at about a depth of 320 feet or at an elevation of 710 feet above sea level)	102		365	
42.	Hard medium dark sandy shale	8		373	

43.	Soft light sandstone	2	375
44.	Hard sandstone	1	376
	Total depth 376 feet.		
	Bottom of hole 654 feet above sea level.		

Drill section No. 18. Near middle NW. ¼ of NW. ¼, sec. 15, Lincoln township.

Curb elevation 888 feet above sea level.

		THICKNESS Ft.	In.	DEPTH Ft.	In.
1.	Soil	8		8	
2.	Sand	2		10	
3.	Yellow clay	9		19	
4.	Sandy clay	4		23	
5.	Dark shale	2		25	
6.	Light shale	4		29	
7.	Light gray sandstone	18		47	
8.	Light shale	2		49	
9.	Light shale	5		54	
10.	Light shale	7		61	
11.	Light shale	3		64	
12.	Black carbonaceous shale	3		67	
13.	Fire clay	8		75	
14.	Limestone	1		76	
15.	Shale	6		82	
16.	White sandstone	3		85	
17.	Light shale	2		87	
18.	Limestone	1	6	88	6
19.	Light shale with fire clay and limestone bands	11	6	100	
20.	Light shale	8		108	
21.	Black slate	3		111	
22.	Light shale	3		114	
23.	Shale with limestone and sandstone bands	10		124	
24.	Sandy shale	55		179	
25.	Hard light sandstone	21		200	
26.	*Coal* (May be horizon of Lower coal)		1	200	1
27.	Red sandstone	5	5	205	6
28.	Dark sandy shale	13		218	6
29.	Sandstone	2		220	6
30.	Dark sandy shales	130	6	351	
	Total depth 351 feet.				
	Bottom of hole 537 feet above sea level.				

Drill section No. 20. One-fourth mile NW. of Inland shaft No. 1, NW. corner of NW. ¼, sec. 9, Lincoln township.

Curb elevation 879.5 feet above sea level.

		THICKNESS Ft.	In.	DEPTH Ft.	In.
1.	Soil and yellow clay	7		7	
2.	Shale, brown	1		8	
3.	Coal, very soft, dirty	2	6	10	6
4.	Fire clay	1	6	12	
5.	Sandstone, red and gray	13		25	
6.	Shale, light and dark	12	6	37	6
7.	*Coal*	1	6	39	
8.	Fire clay	4		43	
9.	Shale, light, sandy in middle	33		76	
10.	Shale, dark	5		81	
11.	*Coal*	1		82	
12.	Fire clay	3		85	

			Thickness Ft.	In.	Depth Ft.	In.
13.	Limestone	may be mixed shales with limestone septaria	1		86	
14.	Shale, light		2	6	88	6
15.	Limestone		1	6	90	
16.	Shale, variegated		11		101	
17.	Limestone			6	101	6
18.	Shale, dark		4		105	6
19.	Limestone, black			6	106	
20.	*Coal*		1	2	107	2
21.	Fire clay		6	10	114	
22.	Shale, variegated		9		123	
23.	Shale, dark		4	5	127	5
24.	*Coal,* bony			7	128	
25.	Sandstone, dark		2		130	
26.	Shale, dark, slaty			10	130	10
27.	*Coal*			2	131	
28.	Dark "slate"		2		133	
29.	Sandstone, light and coarse		6		139	
30.	Shale, light		5		144	
31.	*Coal*			2	144	2
32.	Fire clay			10	145	
33.	Sandstone, light gray		10		155	
34.	Shale, dark, sandy		47		202	
35.	Shale, light, sandy "roof"		6		208	
36.	*Coal,* impure, slaty			9	208	9
37.	*Coal,* pure (Lower)		4		212	9
38.	Fire clay, hard and sandy		6	3	219	

Total depth 219 feet.
Bottom of hole 660.5 feet above sea level.
Top of coal (36) 671.5 feet above sea level.

Drill section No. 21. Northeast corner of NW. ¼ of SW. ¼, sec. 7, Lincoln township.

Curb elevation 907 feet above sea level.

		Thickness Ft.	In.	Depth Ft.	In.
1.	Loam and clay	10		10	
2.	Sand	5		15	
3.	Blue clay	5		20	
4.	Sand, gravel and bowlders	15		35	
5.	Medium soft sandy shale	30		65	
6.	Conglomerate	5		70	
7.	Limy shale	1		71	
8.	Black shale and 3 inches of *coal*		7	71	7
9.	Variegated clay shale	8	5	80	
10.	Sandy shale with clay bands	6	6	86	6
11.	Soft clay shale	3	6	90	
12.	Very hard limestone	1	6	91	6
13.	Very soft reddish clay shale	4	6	96	
14.	Very soft black shale	6		102	
15.	Blue clay shale	6		108	
16.	Very hard limestone	2		110	
17.	Medium soft variegated sandy shale	10		120	
18.	Medium hard clay shale	3		123	
19.	Black shale		6	123	6
20.	*Coal*		6	124	
21.	Coarse sandstone	9		133	
22.	Medium dark medium hard banded shale	21		154	
23.	Dark shale	1	2	155	2
24.	*Coal*	1	6	156	8
25.	Fire clay	1	4	158	
26.	Limestone		6	158	6
27.	Hard variegated shale	11	6	170	
28.	Very hard limestone	1	6	171	6
29.	Hard shale	8	6	180	

30.	Hard streaked sandstone	5		185	
31.	Medium soft streaked sandy shale	20		205	
32.	Medium hard sandstone	22		227	
33.	Soft sandstone with limestone bands	12		239	
34.	Sandstone	6		245	
35.	Limestone	3		248	
36.	Soft sandstone	5	8	253	8
37.	*Coal* (Lower)		2	253	10
38.	Soft sandstone	1	2	255	

Total depth 255 feet.
Bottom of hole 652 feet above sea level.

Drill section No. 22. 1200 feet west, 300 feet south of center of sec. 30, Lincoln township.

Curb elevation 955 feet above sea level (?).

		THICKNESS *Ft.*	DEPTH *Ft.*
1.	Drift	72	72
2.	Shale, light	11	83
3.	Rock, hard	2	85
4.	Shale, light	5	90
5.	Shale, red and white	34	124
6.	Slate, black	4	128
7.	Shale, light	12	140
8.	Shale, red and white	23	163
9.	Shale, darker	7	170
10.	Sandstone	101	271
11.	Shale, sandy	2	273
12.	Sandstone and shale	20	293
13.	Report missing (?) (no coal)	17	310
14.	Shale, sandy	10	320
15.	Rock, hard	1	321
16.	Shale, sandy	20	341
17.	Rock, hard	1	342

Total depth 342 feet.
Bottom of hole 613 feet above sea level.

Drill section No. 23. 874 feet N. and 47½ feet E. of SW. corner of sec. 30, Lincoln township.

Curb elevation 972 feet above sea level.

		THICKNESS *Ft.*	*In.*	DEPTH *Ft.*	*In.*
1.	Soil	7		7	
2.	Clay, yellow	7		14	
3.	Clay, dark	6		20	
4.	Sand	2		22	
5.	Clay, blue	18		40	
6.	Sand	5		45	
7.	Clay, blue	30		75	
8.	Sand	3		78	
9.	Shale, dark bluish	9		87	
10.	Shale, gray, clayey	17		104	
11.	Shale, green	4		108	
12.	Shale, dark	3		111	
13.	*Coal*		11	111	11
14.	Fire clay	3	1	115	
15.	Shale, light	2		117	
16.	Limestone	1		118	
17.	Shale, light	5		123	
18.	Limestone	1		124	
19.	Shale, light	4	6	128	6
20.	Slate, black	1	6	130	

		Ft.	In.	Ft.	In.
21.	Shale, light	28		158	
22.	Pyrite		6	158	6
23.	Shale, dark and light	5	6	164	
24.	Sandstone, hard	2		166	
25.	Shale, light	3		169	
26.	Limestone, black and white	2	6	171	6
27.	Slate, light	7		178	6
28.	Limestone	1		179	6
29.	Shale, dark	3	6	183	
30.	Limestone		6	183	6
31.	Shale, dark and light	13	6	197	
32.	Sandstone, soft	48	6	245	6
33.	Limestone	4	6	250	
34.	Sandstone	3		253	
35.	Shale, sandy	9		262	
36.	Sandstone	6		268	
37.	Limestone	1		269	
38.	Sandstone	47		316	
39.	"Bowlder"	2		318	
40.	*Coal* (Lower)	1		319	
41.	Carbonaceous shale, "slate"		7	319	7
42.	Shale	3	11	323	6

Total depth 323 feet, 6 inches.
Top of coal (40) 654 feet above sea level.
Bottom of hole 648 feet, 6 inches above sea level.

Drill section No. 24. 1000 feet NW. of SE. corner sec. 24, White Breast township.

Curb elevation 960 feet above sea level.

		THICKNESS Ft.	In.	DEPTH Ft.	In.
1.	Drift	62		62	
2.	Shale	3		65	
3.	Clay	5		70	
4.	Shale	18		88	
5.	Slate		9	88	9
6.	*Coal*, impure and slaty	1	9	90	6
7.	Shale	2	6	93	
8.	Sandy shale	14		107	
9.	Dark shale	3		110	
10.	Light shale	12		122	
11.	Red shale	2		124	
12.	Shale	4		128	
13.	Limestone	2		130	
14.	Black fissile shale, "slate"	6		136	
15.	*Coal* (White Breast)		6	136	6
16.	Shale	20	6	157	
17.	Dark shale	2		159	
18.	Shale	14		173	
19.	Limy shale	13		186	
20.	Limestone	3		189	
21.	Shale	2		191	
22.	Black fissile shale, "slate"	4		195	
23.	*Coal* (about No. 11 of Columnar Section)		6	195	6
24.	Shale	4	6	200	
25.	Red shale	4		204	
26.	Sandy shale	7		211	
27.	Sandstone	6		217	
28.	Shale	7		224	
29.	Sandy shale	11		235	
30.	*Coal* (about No. 7 of Columnar Section)	1	5	236	5
31.	Shale		7	237	
32.	Sandstone	8		245	
33.	Sandy shale	8		253	

34.	Black slaty shale	37	8	290	6
35.	Black rock	1	6	292	
36.	*Coal* (Lower)	3	4	295	4
37.	Fire clay		8	296	

Total depth 296 feet.
Bottom of hole 664 feet above sea level.
Top of Lower coal 668 feet above sea level.

Drill section No. 26. 200 feet west of center of sec. 25, White Breast township.

Curb elevation 960 feet above sea level (?)

		THICKNESS Ft.	In.	DEPTH Ft.	In.
1.	Drift	60		60	
2.	Yellow clay of Coal Measures	29		89	
3.	Shale	5		94	
4.	*Coal* and shale	1	6	95	6
5.	Shale	4	6	100	
6.	White shale	12		112	
7.	Black shale	4		116	
8.	*Coal* (White Breast ?)	1	2	117	2
9.	Shale	9	10	127	
10.	Limestone	2		129	
11.	Shale	18		147	
12.	Red shale	7		154	
13.	Shale	4		158	
14.	Limestone	2		160	
15.	Shale	46		206	
16.	Black shale—slate	5		211	
17.	*Coal*	1		212	
18.	Shale	8		220	
19.	Rock	2		222	
20.	Sandy shale	12		234	
21.	Sandstone	11		245	
22.	Sandy shale with sandstone partings	45		290	
23.	*Coal* (Horizon of Lower coal)		6	290	6
24.	Shale	13	6	304	
25.	Red shale and rock	6		310	
26.	Red shale	11		321	
27.	Sandstone	25		346	
28.	Light sandy shale	3		349	
29.	Sandstone	12		361	
30.	Light sandy shale	18		379	
31.	Sandy shale	12		391	
32.	Sandstone	9		400	

Total depth 400 feet.
Bottom of hole 560 feet above sea level.
Top of coal (No. 23) 670 feet above sea level.

Drill section No. 29. Shaft of Daniel's (Big Hill) mine near railway track at Lucas.

Curb elevation 900 feet above sea level.

		THICKNESS Ft.	DEPTH Ft.
1.	Alluvium, etc.	10	10
2.	Blue shale	10	20
3.	Light clay, "mud", may be fire clay	4	24
4.	Blue shale	25	49
5.	*Coal*	1½	50½
6.	Fire clay	6½	57
7.	Shale	42	99
8.	*Coal*	2	101
9.	Fire clay and clay shale	12	113
10.	Shale	125	238

		Thickness Ft.	Depth Ft.
11.	Sandstone and shale, ''slate''	40	278
12.	*Coal* (Lower or ''Thick Vein''), irregular	3–9	
13.	Fire clay		

Top of coal (12) 622 feet above sea level.

Drill section No. 32. Southeast corner of SW. ¼ of SW. ¼, sec. 36, English township.

Curb elevation 976 feet above sea level.

		Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
1.	Surface soil	27		27	
2.	Sand	8		35	
3.	Clay	23		58	
4.	Gravel	3		61	
5.	Sand clay and gravel	51		112	
6.	Hard blue rock	1		113	
7.	Hard dark shale	12		125	
8.	Hard blue rock		9	125	9
9.	Hard dark shale	7	3	133	
10.	Hard medium dark shale	7		140	
11.	Soft medium light shale	4		144	
12.	Hard medium light shale	4		148	
13.	Limestone		6	148	6
14.	Hard dark shale	3	6	152	
15.	*Coal* (No. 11 of Columnar Section)	1	3	153	3
16.	Soft light shale	3	9	157	
17.	Hard limy shale	2		159	
18.	Soft light shale	4		163	
19.	Soft light sandstone	6		169	
20.	Soft medium dark shale	5		174	
21.	Hard medium dark shale	3		177	
22.	*Coal* (No. 7 of Columnar Section)		6	177	6
23.	Soft medium light shale	4	6	182	
24.	Hard medium dark shale	6		188	
25.	Hard medium light shale	3		191	
26.	Hard medium dark shale	5		196	
27.	*Coal* (No. 5 of Columnar Section)	1		197	
28.	Hard medium dark shale	39	9	236	9
29.	*Coal* (Lower)	5	4	242	1
30.	Hard dark fire clay	11		243	
31.	Medium hard light fire clay	2		245	

Total depth 245 feet.
Bottom of hole 736 feet above sea level.
Top of coal (29) 739 feet above sea level.

Drill section No. 33. Near center east side sec. 35, English township, 20 feet below the upland.

Curb elevation 986 feet above sea level.

		Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
1.	Surface soil	31		31	
2.	Blue clay	19		50	
3.	Sand with clay streaks	57		107	
4.	Gravel and bowlders	2		109	
5.	Quicksand	25		134	
6.	Soft clay shale	5		139	
7.	Hard medium dark shale	1		140	
8.	Hard fossiliferous limestone		8	140	8
9.	Hard medium dark shale	5	4	146	
10.	Hard dark shale	4		150	
11.	Soft light shale (limestone nodules)	6		156	
12.	Medium light hard shale	4		160	

13.	Hard variegated shale	5		165	
14.	Medium light hard shale	11		176	
15.	Hard medium dark shale	5		181	
16.	*Coal*		6	181	6
17.	Fire clay	3	6	185	
18.	Soft medium light shale (Limestone nodules)	11		196	
19.	Medium soft variegated shale	4		200	
20.	Hard medium dark shale	3	10	203	10
21.	*Coal*		9	204	7
22.	Medium hard medium dark shale	4		208	7
23.	Soft light shale	4		212	7
24.	Soft light sandstone	7	5	220	
25.	Hard medium dark shale	10		230	
26.	Sandstone	3		233	
27.	Hard medium dark shale	8		241	
28.	*Coal*	1	6	242	6
29.	Medium light medium hard sandstone	1		243	6
30.	Soft light sandstone	3		246	6
31.	Hard dark shale	14		260	6
32.	Hard medium dark shale (streaked)	3		263	6
33.	Hard blue rock	1		264	6
34.	Hard medium dark sandy shale	3		267	6
35.	Sandstone	4		271	6
36.	Streaked sandy shale	14		285	6
37.	Hard medium dark sandy shale	12		297	6
38.	Soft light sandstone	3		300	6
39.	Hard blue rock	1		301	6
40.	Hard medium dark shale sand streaks	44		345	6
41.	Hard light sandstone	2	6	348	

Total depth 348 feet.
Bottom of hole 638 feet above sea level.

Drill section No. 34. Near center (NW. of) sec. 24, English township.

Curb elevation 899 feet above sea level.

		THICKNESS		DEPTH	
		Ft.	*In.*	*Ft.*	*In.*
1.	Surface soil and clay (alluvium ?)	16		16	
2.	Shale, medium hard, light and dark	33		49	
3.	*Coal* (Wheeler ?)	1	1	50	1
4.	Shale, hard, light	8	11	59	
5.	Limestone, hard, may be Two Layer	1	6	60	6
6.	Shale, hard, light, lower part variegated	11	6	72	
7.	Limestone		6	72	6
8.	Shale, hard and medium dark	4	6	77	
9.	*Coal,* may be White Breast		9	77	9
10.	Shale, medium light, soft and hard	12	3	90	
11.	Sandstone	3		93	
12.	Shale, hard, medium dark	7	7	100	7
13.	*Coal*		5	101	
14.	Shale, medium hard, medium light and dark	11	6	112	6
15.	*Coal*	1	6	114	
16.	Sandstone, light	2		116	
17.	Shale, hard and medium dark	45	6	161	6
18.	Shale, carbonaceous	1	3	162	9
19.	*Coal,* middle 18 inches slaty and bony	6	10	169	7
20.	Sandstone, light	7	5	177	
21.	Shale, medium hard, light, sandy	8		185	
22.	Shale, hard, dark	3		188	
23.	Shale, limy	1	6	189	6
24.	Shale, light, sandy	1		190	6
25.	Sandstone	1	6	192	
26.	Shale, limy	1		193	

27.	Shale, hard, medium dark, sandy	3		196	
28.	Sandstone	3		199	

Total depth 199 feet.
Bottom of hole 700 feet above sea level.
Top of Lower coal 735 feet above sea level.

Drill section No. 37. Middle north side of NE. ¼ sec. 23, English township.

Curb elevation 932 feet above sea level.

		THICKNESS Ft.	In.	DEPTH Ft.	In.
1.	Surface soil and loess (?)	10		10	
2.	Sand and clay	14		24	
3.	Blue clay (drift)	36		60	
4.	Shale, soft, dark	6		66	
5.	*Coal*		6	66	6
6.	Shale, light, medium hard	12	6	79	
7.	Shale, hard and medium light	3		82	
8.	Shale, soft and variegated	2		84	
9.	Limestone	1		85	
10.	Shale, hard, medium dark	5		90	
11.	*Coal*		6	90	6
12.	Shale, hard, medium dark	1	6	92	
13.	Shale, soft, medium light, limestone nodules	6		98	
14.	Shale, medium soft, variegated	7		105	
15.	Shale, hard, light, sandy	3		108	
16.	Shale, hard, medium dark	11		119	
17.	*Coal*		6	119	6
18.	Shale, hard, dark	7	6	127	
19.	*Coal*	1	3	128	3
20.	Shale, hard, medium dark	30		158	3
21.	*Coal*	3	9	162	
22.	Sandstone, medium hard, light	1		163	
23.	Shale, medium hard, light, sandy	5		168	
24.	Rock, hard, gray	2		170	
25.	Shale, hard, light	3		173	
26.	Rock, hard, gray		3	173	3
27.	Shale, medium light, sandy	3	4	176	7
28.	Shale, medium dark	6		182	7
29.	Limestone, hard	1		183	7
30.	Shale, medium dark, banded	17		200	7
31.	Sandstone, shale bands	10	5	211	

Total depth 211 feet.
Bottom of hole 721 feet above sea level.
Top of coal (21) 774 feet above sea level.

Drill section No. 38. North of center of NW. ¼, sec. 32, English township.

Curb elevation 966 feet above sea level.

		THICKNESS Ft.	In.	DEPTH Ft.	In.
1.	Surface soil	18		18	
2.	Soft clay	9		27	
3.	Soft clay shale	11		38	
4.	Soft medium light shale	3		41	
5.	*Coal* (Wheeler)	1		42	
6.	Soft medium light shale	9		51	
7.	Limestone, Two Layer	1		52	
8.	Soft medium dark shale	6		58	
9.	Limestone	1	(?)	59	
10.	Dark shale	1		60	
11.	*Coal* (White Breast), two layers separated by 1 foot carbonaceous shale	3		63	
12.	Soft, light shale	10		73	

13.	Soft variegated shale	2		75	
14.	Soft light shale	4		79	
15.	Medium hard variegated shale	5		84	
16.	Medium soft medium dark shale	3	10	87	10
17.	*Coal*	1	2	89	
18.	Hard light sandy shale	5		94	
19.	Hard medium dark shale	8		97	
20.	*Coal*		6	97	6
21.	Soft medium light shale	10	6	108	
22.	Hard medium dark shale	5		113	
23.	*Coal*	1	6	114	6
24.	Soft medium light shale	3		117	6
25.	Limestone	1	6	119	
26.	Soft light shale	4		123	
27.	Medium soft variegated shale	5		128	
28.	Soft light sandy shale	2		130	
29.	Hard dark shale	5		135	
30.	Medium soft sandstone	5		140	
31.	Limestone	2		142	
32.	Hard medium light shale	6		148	
33.	Hard medium dark shale	2		150	
34.	Carbonaceous shale	2		152	
35.	Hard medium dark shale	66		218	
36.	Sandstone	16		234	

Total depth 234 feet.
Bottom of hole 732 feet above sea level.

Drill section No. 39. Near south center sec. 32, English township.

Curb elevation 865 feet above sea level.

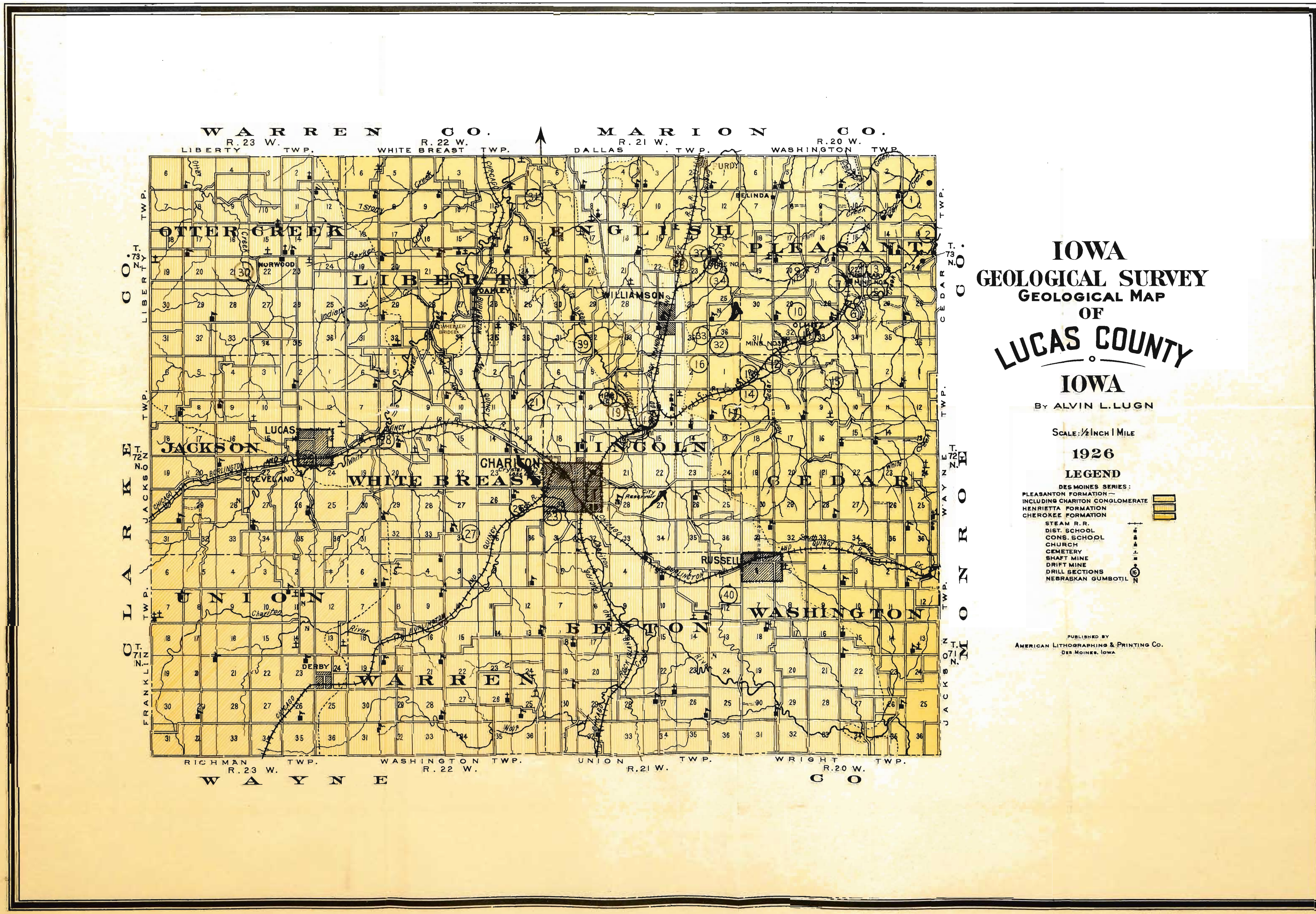
		THICKNESS Ft.	In.	DEPTH Ft.	In.
1.	Sandy soil	12		12	
2.	Sand and gravel	5		17	
3.	Soft light shale	7		24	
4.	Medium soft dark shale	2		26	
5.	Medium soft light shale	15		41	
6.	Limestone	1		42	
7.	Medium soft light shale	8		50	
8.	*Coal*	2		52	
9.	Soft medium light shale	6		58	
10.	Medium hard light sandstone	9		67	
11.	Medium hard dark shale	8		75	
12.	*Coal*		6	75	6
13.	Soft light shale	1	6	77	
14.	Dark shale with coal bands	2		79	
15.	Light sandy shale	16		95	
16.	Hard medium dark shale	20		115	
17.	Hard blue rock	1		116	
18.	Hard dark shale	2		118	
19.	Hard medium dark shale	25	6	143	6
20.	*Coal* (Lower)	4	9	148	3
21.	Medium soft medium dark shale		3	148	6
22.	Medium hard light sandy fire clay	1		149	6

Total depth 149 feet, 6 inches.
Top of coal (20) 721 feet, 6 inches above sea level.
Bottom of hole 714 feet, 6 inches above sea level.

The Cackler mine shaft. Northeast corner of section 2, Otter Creek township.

Curb elevation 960 feet above sea level.

		FEET
1.	Clay and gravel	10 to 12
2.	Shale, blue	5
3.	Rock, hard	12
4.	*Coal*	1/3
5.	Shale, sandy and with limestone bowlders	8
6.	Limestone (?)	8
7.	? (record uncertain)	14
8.	Shale	5
9.	*Coal*	1/3
10.	Fire clay	2
11.	Clay, blue-gray	2
12.	Shale	6
13.	*Coal*	1½ to 2⅓
	Total depth 76 feet.	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